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Rudiments of Geology.

SHARP.

RUDIMENTS OF GEOLOGY.

RUDIMENTS

OF

GEOLOGY.

BY

SAMUEL SHARP, F.S.A., F.G.S.

PART I.

INTRODUCTORY.

PART II.

STRATIGRAPHICAL AND PALÆONTOLOGICAL.

LONDON:
EDWARD STANFORD, 55, CHARING CROSS.
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TO

JOHN EVANS, ESQ.,

VICE-PRESIDENT OF THE ROYAL SOCIETY,

PRESIDENT OF THE GEOLOGICAL SOCIETY,

VICE-PRESIDENT OF THE SOCIETY OF ANTIQUARIES,

PRESIDENT OF THE NUMISMATIC SOCIETY,

ETC. ETC.;

WHO TO MANY OTHER ACTS OF KINDNESS TO THE AUTHOR

HAS ADDED HIS PERMISSION OF THIS

DEDICATION.

May, 1875.

PREFATORY NOTES.

The First Part of this Initiatory Book was prepared for and used in MS. by my private class. I found that, for a continuance of such use, it would be necessary to have it printed; and I have taken advantage of the opportunity to add the Second Part. I have endeavoured in this to epitomize, in as small a compass as possible (although the latter portion has undesignedly expanded in preparation), the general results of discoveries in Stratigraphical and Palæontological Geology brought down to a recent date and to convey a comprehensive idea of the Stratigraphical and Life History of the Earth.

In the Table of Classification of Formations (facing page 23), the "Approximate Maximum Thicknesses" may appear excessive, and the Total startling: these thicknesses, however, have been gathered from authorities worthy of respect, and the Total is a necessary result.

The Formations described have been mainly those of this country: but, as Professor Ramsay has remarked, "England is the very Paradise of Geologists; for it may be said to be

in itself an epitome of the Geology of almost the whole of Europe, and much of Asia and of America." *

Should this Book be employed for Class purposes, it would be well for the Teacher to accompany its use with *verbal explanations*, and with reference when needful to a good *Geological Map*: the best for such a purpose is that of England and Wales by Professor Ramsay.

As a means of acquiring familiarity with Fossil Life-Forms, each Student should possess "*A Tabular View of British Fossils*," which contains 600 figures excellently engraved by Lowry; and it would be desirable that, when practicable, he should frequently examine good specimens of Fossils of characteristic genera and species. Short local Field Excursions would also be a great help.

I have culled information from many sources, and have given my authorities in foot-notes: any not so given have been omitted inadvertently. Mr. Etheridge, F.R.S., has kindly revised my Palæontology.

SAMUEL SHARP.

Dallington Hall, Northampton,
May, 1875.

* *Physical Geology of Great Britain*, page 72.

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CORRIGENDA.

Page 4, last line. For "action of fire or great heat"—*read*, action of great internal heat.

„ 5, paragraph *d*. For "rocks"—*read*, beds.

„ 11. For "Mountains of considerable height near Turin, named the 'Superga,' have"—*read*, Hills of considerable height have.

„ 31, line 10. For "Corals"—*read*, *Polyzoa* (allied to *Corals*).

„ 35, last line but one. After "Devonshire"—*read*, Gloucestershire, and West Somersetshire.

„ 36, last line. The "advent of Oysters proper" should have been placed under the *Lower Lias*.

„ 42, line 7 from bottom. For "bivalve"—*read*, univalve.

„ 57, line 7. For "four to five feet long"—*read*, the largest examples of which are under five feet in length.

„ 64, note †. For "Sec. 28"—*read*, Sec. 21.

„ 74, line 14. For "these are connected"—*read*, these are *occasionally and in places* connected.

„ 90, Sec. 39, par. *a*, line 5, at the end. For "Lower Eocene"—*read*, Upper Eocene.

RUDIMENTS OF GEOLOGY.

PART I.

1. The derivation and meaning of the word "Geology."

It is derived from two Greek words, "*ge*," the Earth, and "*logos*," a discourse; and it means *the study of the Earth.*

2. The difference between the sciences of Astronomy and Geology.

Astronomy is the study of the stars and of *the Earth as a stellar object*—as an integral *part* of a stellar system.

Geology is the study of the *Earth as a whole*, as being complete in itself.

3. The *broad* meaning of the term "Geology" is the study of the Earth and of *all* that belongs to the Earth.

The *scientific and applied* meaning of the term is the study of all the materials of the Earth *lying beneath its surface.*

4. Geology has been divided into:—

a. Stratigraphical Geology—derived from the Latin word "*stratum*," anything covering another, and the Greek word "*grapho*," I write.

b. Palæontological Geology—from the Greek words "*palaios*," old, "*onta*," existing things, and "*logos*," a discourse.

c. Physical Geology—from the Greek "*physis*," nature.

a'. Stratigraphical Geology is the study of the layers, or beds, or *strata*, in which the materials of the Earth's surface are found to be arranged.

b'. Palæontological Geology is the study of the remains of *animals* and *plants* which the strata of the Earth are found to contain; and these remains are called "*fossils*"—from the Latin word "*fossilis*," that which is dug out of the earth.

c'. Physical Geology is the study of the *natural causes* and *origin* of the different strata and their contents, of the existing arrangement of land and sea, and of the present surface contour—*i.e.* the occurrence of hill and dale, mountains and plains, rivers and lakes and seas; and, in some phases, it is nearly allied to Physical Geography.

5. The chief objects of Geological inquiry are:—

The materials, nature, fossil contents (both animal and vegetable), order, origin, and relative ages, of the strata making up the so-called "*crust*" of the Earth.

The solid materials of the Earth are estimated to extend downwards from the surface to a depth of 23 miles; below which depth, it has been considered that the Earth's matter is in a molten or fluid condition, owing to the great heat of the interior of the Earth—[a conclusion, however, subject to modification hereafter]. The Earth is roughly 8,000 miles in diameter; and, as the solid materials have only a thickness of 23 miles, measuring from the surface, they have been termed the "crust" of the Earth.

The term "crust" of the Earth has also been used as indicating that solid portion of the Earth's mass which (by natural processes to be hereafter described) have been brought within the reach of Man's observation.

6. All substances with which we are familiar in daily life are derived directly or indirectly from stratified or unstratified rocks or beds included in the objects of the Geologist's study; such as:—

a. Directly—Stone of various kinds for building, clay for bricks, slate for roofs, etc., marble (for statuary, pillars, chimney-pieces, and hearth-slabs), coal, limestone, sand, gravel, granite and other stone for roads, ores of the various metals (iron, copper, tin, zinc, lead, gold, silver, etc.), all precious stones, rock salt, and many other things.

b. Indirectly—Spring and river waters, manufactured salt, gas for lighting, paint and many drugs, all metals, the soil upon which the vegetable world exists, etc., etc.

c. Still more indirectly—Plants, animals, our food, and Man himself.

7. The *useful, moral,* and *religious,* results of the pursuit of Geological science.

The *useful* results of Geological science are found in the knowledge it affords:—

a. Of the nature of the materials of the Earth's strata, of the localities and depths from the surface at which they are found, of the facilities which may exist for their being obtained, and of the applicability of their products to the purposes of life. Examples—the substances enumerated in the last Section, namely, water from springs and wells, coal, stone, lime, clay, salt, all metals, etc.

b. Of the nature of soils and substrata for the purposes of cultivation.

c. Of the stability or instability of underlying beds in the question of obtaining firm foundations for buildings.

The *moral* results of the pursuit of Geology are traceable, not only in an increase of knowledge and enlightenment, but in the fact that, in the practical application of that knowledge, the personal comfort and consequent refinement of society is promoted, and thus civilization is advanced.

The *religious* results of Geology are to be recognized in an appreciation of such wonderful works of Creation as Geology alone has been able to open up to our knowledge—works of Creation, both animal and vegetable, of such varied, strange, and multitudinous forms, as to exceed in interest and greatly to out-number the different kinds of animals and plants existing upon the Earth at the present time; serving to display the all-skilful, all-wise, and all-benevolent creative works of the Deity upon the Earth, extending back through ages of progressive changes in the physical conditions of the Earth's surface, so prolonged as to be only paralleled by the profound distances in space and incalculable periods of time which Astronomy discloses.

8. The various materials of the Earth within the scope of our observation, which apparently have been accidentally distributed in different localities and at various depths, occur in a certain order of *vertical sequence*, having been so arranged by the necessary operation of natural laws; which laws have operated through all time and all over the Earth, and are even now operating.

9. The materials of the Earth's crust may be classed into two principal Divisions—the *Igneous* and the *Aqueous*.

a. The Igneous are those which have been formed by the action of fire or great heat—such as granite, the original

foundation and source of all rocks; and such as lava and other materials which have been thrown up by volcanos.

b. The Aqueous are those which have been formed by the agency of water (at the bottoms of rivers, lakes, estuaries, and seas), and are for the most part sedimentary. Limestone Rocks are chiefly composed of matter derived originally from animal life. Among these are a class of rocks which may be termed Aqueous, but which are not sedimentary—Coralline Rocks, which have been built up, in the forms of coral reefs and coral islands, by the so-called "coral insect"; which is not an insect at all, however, but a *Zoophyte*—from the Greek words "*zoon*," an animal, and "*phyton*," a plant—it having been formerly mistakenly supposed that this class of life-forms presented a connecting link between animals and plants.

c. There are other rocks, constituting a kind of Intermediate Division, and partaking to a certain degree of the nature of each of the former Divisions: these are rocks which have been originally formed by Aqueous action, and entirely altered by contact with heated Igneous rocks deep under ground. These are called "Metamorphic" rocks—from the Greek words "*meta*," change, and "*morphe*," form —indicating that their form has been changed. The so-called Hartshill granite, so much used about Northampton for the roads, is a "metamorphosed" rock.

d. There is another class of rocks, such as peat, lignite, and coal, which do not bear so large a proportion to the whole as either of the foregoing; which may be termed Semi-aqueous, having been formed, for the most part, in warm marshes or "savannahs"; and which have been derived from vegetable growth.

10. The labours of Geologists are devoted more generally to the *Aqueous* Division—

a. As presenting the greatest aggregate thickness of beds accessible to observation.

b. As exhibiting the greatest variety in the nature of the materials of which its beds are composed.

c. As its beds are almost exclusively those which contain the remains of organic forms called fossils.

d. As pointing to the most varied physical causes of the formation of strata, and of Geological changes.

And to this Division, therefore, in the first instance, will our attention be directed.

11. The order of succession (otherwise called "vertical sequence") of beds in the neighbourhood of Northampton* is as follows:—

	Duston and Kingsthorpe.	*Northampton.*	*Great Houghton and Blisworth.*
1	. . . . .	. . . . .	Clay.
2	Limestone.	. . . . .	Limestone.
3	Brick Clay.	. . . . .	Clay.
4	Sand and Sandstone.	Sand and Sandstone.	Sand.
5	Red Building Stone.	Red Building Stone.	Red Stone.
6	Ironstone.	Ironstone.	Ironstone.
7	Brick Clay (Lias).	Brick Clay (Lias).	Brick Clay (Lias).

12. In other parts of this country and of the world (whatever stratified beds occur), the same kind of order of succession is everywhere found to prevail.

13. The Geological terms "*stratum*" and "*bed*" mean nearly the same thing. A stratum is a horizontal layer of

* In lieu of illustrations presented in these Sections, the sequence of beds in any locality may be adopted.

material, of whatever kind, which does not admit of re-division, and varies in thickness from a few inches to a greater or lesser number of feet.

14. A "*formation*" may consist of one "stratum" or of a group of a few or many "strata." The question of what constitutes a "formation" is determined by a variety of considerations, such as—identity of material (sometimes), uniformity of fossil contents, identity of position in a vertical sequence, or the fact that the area can be defined over which a distinguishable stratum or group of strata occurs, etc.

Thus—*a*. The Clay and Limestone, Nos. 1 and 2 of the Northampton * series, are both of marine origin, and contain the same kind of fossils; but, one being clay and the other limestone, and in vertical succession, they are distinct formations: the limestone formation, be it noted, consisting of several strata, varying in thickness, hardness, and mineral character.

b. The Clay, No. 3, is a distinct formation; for its contents tell us that it was formed in the estuary of a large river.

c. The Sand and Sandstone, No. 4, is a distinct formation; for, although also of estuarine origin, there comes between it and No. 3, in the Northern parts of the county, a thick bed of marine limestone, indicating that a long period of time had intervened between the formation of the one and of the other, and that the estuaries in which they were deposited were not the same.

d. The Red Building-stone and the Ironstone, Nos. 5 and 6, constitute one formation, as the difference occurs only locally:

* See Note on page 6.

in some places, the upper (No. 5) contains more iron than the lower (No. 6), and over a wide district in the Northern parts of the county there is very little iron in either. The area of this formation is pretty clearly defined—as spreading, from Mid-Oxfordshire, through Northamptonshire, Rutland, Lincolnshire, into Yorkshire, as far north as Whitby. This formation, therefore, will come under the last-named indication of what constitutes a "formation."

e. The Brick Clay (Lias), No. 7, being a clay, and containing a very distinct group of fossils, is a distinct and very important formation.

f. It will have been perceived that all these Northampton formations are of Aqueous origin.

15. The processes by which Sedimentary strata have been formed "at the bottoms of rivers, lakes, estuaries, and seas." [Section 9, par. *b.*]

All Sedimentary strata have been formed from the materials of pre-existing rocks, which have been wasted by a process called "denudation"—from the Latin word "*denudo*," to strip, to bare. There are several kinds of "denudation":—

a. "*Sub-aerial*" denudation—from the Latin "*sub*," under, and "*aer*," the air. The effect of frost and snow and rain upon the surface of the Earth is continually to wear away that surface, especially in mountainous regions. Frost shatters or softens the harder materials: snow and rain shower down water upon the surface, causing a general flow from higher to lower levels. During thaw or rain, may be seen small muddy streams pouring down the hilly roads, and depositing a thick sediment at the level bottoms. When there is a flood, the water is always muddy, from the

material washed from the higher grounds: by and by, the flood subsides, and the water of the river clears, because the mud which discoloured it has been either deposited on the meadows or carried down by the stream to be deposited elsewhere. Thus, the material of higher levels is ever being conveyed by rills into rivulets, by rivulets into brooks and streams, by these into rivers, and by rivers into "valleys, lakes, estuaries, and seas."

Hence great mud banks and other accumulations are formed at the mouths of rivers—such as abound in the great Lincolnshire Wash, into which flow the Ouse, the Nene, the Welland, rivers all rising in Northamptonshire, and the Witham which rises in Rutland; hence also have we large accumulations of sediment in the estuaries of the Thames, the Severn, the Southampton river, in England, the Shannon in Ireland, and in the Firths in Scotland.

So, by the melting of the ice and snow of the higher Alps in spring, small streams are converted into torrents, and an incalculable amount of material is carried downwards—the lake of Geneva is being rapidly shallowed, and its area at its Eastern extremity diminished, by the deposits of mud brought down by the Upper Rhone. The great rivers of South America, and the Ganges and Indus of India, each annually carries to the ocean many millions of tons of denuded matter. The whole flat country of Egypt has been formed by deposits of the Nile, brought by its Eastern branch from Abyssinia, and by its main course from more Southerly districts, reaching nearly to the Equator.

The whole land-surface of the Earth, by this process of sub-aerial denudation, is constantly contributing materials

to the ever-accumulating deposits at the bottom of the ocean.

Many valleys, through the meadow flats of which small rivers now flow, have been excavated by those very rivers, when of greater volume, and under more favourable conditions, and the abraded materials carried down to the sea.

b. "*Marine*" denudation. The sea is always encroaching upon the land: wherever upon the sea-shore you see a cliff, there you have evidence of marine denudation—a cliff is merely the vertical section of land from which other land has been cut away by the sea as with a knife: this process is universally going on. A cliff is gradually hollowed out and undermined at its base, by the force of the waves; the face and upper portion of the cliff become fissured and loosened by frost and rain, and at length topple down upon the shore below; this loose material ("*detritus*" it is called, from the Latin "*detritus*," worn) is then carried away by the tides and sea-currents, and is deposited as sediment at the bottom of the ocean. This process of marine denudation has led to many falls of cliffs at Dover and other parts of England—whole estates have gradually disappeared in this way; and in the North of Norfolk, this waste is occurring to such an extent, that it is thought that the present site of the pleasant town of Cromer will in a generation or two become a continuous part of the bottom of the neighbouring sea. Sea-bottoms are also sometimes abraded by oceanic currents.

c. "*Glacial*" denudation. This is the waste of the higher peaks of mountains by the disintegrating effects of frost, and of the sides and bottoms of valleys filled with ice, called

glaciers. Glaciers have always a downward grinding motion, and they tear and wear away the rocks with which they come into contact: this very downward motion conveys to the bottoms of the valleys—to the lower ends of the glaciers (which are there continually melting away)—the materials denuded by these two causes; and these materials are there deposited in huge banks, called "*Moraines*" (a French word). Mountains of considerable height near Turin, named the "Superga," have been thus formed by the ancient glaciers of the Southern side of the Alpine chain; and traces of "Moraines" are to be found in the valleys of every mountainous district in which glaciers of important size have at any time occurred. In the Northern and Southern polar regions of the Earth, the lower ends of mighty glaciers run down into the ocean, are broken off by the action of the sea, and are floated away as "icebergs" (or ice-mountains), laden with great masses of rock and other materials torn from the bottoms and sides of the valleys in which they have been formed; and these rocks and materials, as the icebergs melt, fall to the bottom of the ocean.

16. The three several forms of denudation described, and the consequent processes of aqueous deposition, are such as even now are in operation—and are the same as have produced, during various periods of remote time, all the different kinds of sedimentary rocks.

These various phenomena of nature, with which modern Physical Geography makes us acquainted, are held to be identical with the natural phenomena to which Physical

Geology traces up the formation of all the sedimentary beds of the Earth's crust.

17. How the various forms of animal and vegetable life (now known as fossils) became enclosed in the sedimentary rocks.

The waters of seas, estuaries, lakes, and rivers, abound with forms of life, and have done so from remote epochs of Geological time—it has ever been an ordained law of life that death should succeed life, even as the night succeeds the day: it has always been that all living things die.

a. The ocean bed forms the sepulchre of all things that have lived in the ocean—shells of mollusca, bones and scales of fishes, skeletons of sea mammals and birds, the carapaces and bones of turtles, the hard cases of lobsters, crabs, and other crustacea, star-fishes, the stony frames of zoophytes, and sea-weeds, are ever being embedded in the continuously accumulating sediment of the sea-bottoms; and to these are added a very few (proportionately) land animals and plants, and shells of fresh-water mollusca, brought down by streams.

b. The deposits in estuaries contain the remains of animal forms which thrive best in the alternation or admixture of salt water and fresh water; and these are commingled with fresh-water remains, brought down by the streams, and with marine remains, brought up by the tides.

c. The deposits in lakes and rivers contain only the remains of fresh-water forms of life, with the occasional accidental introduction of land forms of life.

It is thus, by a study of the nature of the organic remains (or fossils) which a formation contains, that

Geologists are enabled to determine whether such formation had its origin in a marine, or in an estuarine, or in a fresh-water deposit.

18. How it is that strata deposited at the bottom of the ocean, and containing marine fossils, are found at considerable distances from the sea, and at considerable elevations above the sea-level; and that estuarine, lacustrine, and alluvial strata, in like manner, are found in situations where estuaries, lakes, and rivers, do not now exist.

Even from the time when first the Earth obtained a solid crust, every part of its surface has been alternately rising and sinking—parts of its surface are rising at the same time that other parts are sinking; but these upward and downward movements are so slow as to be inappreciable, except by careful observation.

Thus:—

a. It has been found that for some centuries the Northern districts of Norway and Sweden have been rising, and that Greenland has been sinking, at about the rate of two feet in 100 years.

b. The Western coasts of Southern Italy are slowly rising. During the last 1200 years, the ruins of the temple of Jupiter Serapis at Pozzuoli, near Naples, have sunk some 25 feet beneath the water of the Bay, and have risen again to about their previous level—as indicated by multitudes of holes bored by a small stone-boring sea-bivalve called "*Lithodomus*" (from the Greek "*lithos*," a stone, and "*domos*," a house) in three standing columns at a height of 23 feet from their bases: so that these columns must have been immersed

in the sea to that depth, and have again risen to their present position, by the alternate sinking and rising of the land.

c. In the Southern Pacific Ocean, many of the numerous coral islands are found to be rising, whilst others are sinking.

The portions of the Earth's surface which are thus rising are called "areas of elevation"; those which are sinking "areas of depression."

Every portion of the Earth's surface has been alternately land and sea; and this, throughout the area of this country, over and over again.

Thus, by the combined action of denudation and the alternate elevation and depression of the Earth's surface in areas, all the sedimentary rocks, as we find them, have been formed and placed; and thus, by the operation of the same processes, are even now accumulating, upon the deep floors of seas, sedimentary beds, which, in some far remote future, will constitute the fossiliferous strata of wide continents of dry land, occupying areas now covered by the profound waters of mighty oceans.

19. Beds having the same mineral character have not always the same Geological origin.

For example, there are several kinds of gravel, three kinds of chalk, and many kinds of clay, limestone, sandstone, etc., all of which belong severally to different formations. Moreover, in tracing out the areas of formations, it is often found that limestone, in its horizontal extension, passes into sand or sandstone, and these into clay,—or the reverse. These variations in the materials of any one bed are mainly the result of corresponding local variations in

the materials of the pre-existing rocks, which, having been wasted by denudation, were re-deposited during the period of the formation of that bed.

The mineral character of a bed, therefore, is by itself no indication of the Geological formation to which that bed belongs.

20. A stratum or bed is to be identified as belonging to any particular Geological formation by its *fossil contents.*

a. This is quite a modern discovery. In very ancient times, the occurrence of marine shells and other fossils, sometimes at great heights above the level of the sea, and sometimes at great depths in the Earth, had been observed, and led to various and often very wild speculations; but until nearly the close of the last century, no attempt had been made to associate certain fossils with particular Geological beds, or to establish any systematic classification of Geological strata, either as to area or to vertical sequence.

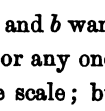
b. This was at length accomplished by WM. SMITH; who, in consequence, has been styled "The Father of Geology"—because upon this great discovery is chiefly based the present structure of Geological Science; and he is justly considered to rank with the greatest scientific discoverers of this century. He was born of humble parents, at Churchill, in Oxfordshire, in 1769; and he died, in 1839, at Northampton, and was buried in St. Peter's Churchyard at that town.

c. Wm. Smith early in life began to collect fossils, and the slight elementary knowledge he thus acquired led him, when he became a surveyor and an engineer, to examine closely the fossils contained in the different rocks with which the

pursuit of his occupation made him acquainted. He found that each separate bed contained a separate, a distinct, set or series of fossils; so that he was ultimately enabled to identify by its fossil contents any bed with which he had been previously acquainted, wherever it might be situated, and whatever might be its mineral character.

d. This led him to make a further great discovery. I have enumerated the several Geological beds which occur in the neighbourhood of Northampton, and described the order of their "vertical sequence." [See Table, Section 11.] Wm. Smith, in prosecuting his work as to the identification of beds, found that their relative position in a vertical sequence never varied.

Supposing he found five beds (which we will call *a*, *b*, *c*, *d*, *e*) in some locality placed one upon another thus— he might find elsewhere *a* lying upon *c* and *b* wanting, or *b* lying upon *e* and *c* and *d* absent, or any one bed lying upon any other bed *lower* in the scale; but he never found *c* lying upon *a*, nor *e* upon *b*, nor any bed overlying another bed which had previously been above it. This order in the vertical relative position of beds has been confirmed by all subsequent investigation.



e. Wm. Smith also discovered that, although in a limited district Geological beds may be apparently horizontal (piled up one upon another vertically like the storeys of a house), yet, when examined over a wider expanse of country, they are found to lie in a slanting and overlapping position, like pieces of bread and butter on a plate, portions of all in succession coming to the surface.

This is a result of internal movements in the Earth's crust, described in Section 18.

This fortunate disposition of Geological beds brings the whole (notwithstanding their immense aggregate thickness) within reach of the examination of Geologists.

21. Geological terms used in reference to peculiar dispositions of Geological beds.

a. When a bed, from being inclined, passes under other beds, it is said to "*dip.*" When a bed rises above another bed, and thus, from between two beds, comes to the surface, it is said to "*crop out.*" The direction of the "dip" is necessarily directly opposite to that of the "out-crop." Thus, the same bed "dips" in one direction, and "crops out" in the opposite direction.

b. The portion of the bed which thus "crops out" extends in a line at right angles to that of the "dip" and "out-crop," and is called "*the strike,*"—from the German "*streichen,*" a word adopted by German Geologists, and meaning "to extend," "to have a certain direction."

c. Sometimes beds become thinner and thinner, until they cease: this is called "*thinning out.*"

d. An "*escarpment*" is an inclined surface (such as the border of a valley, the side of a hill or mountain, or the rise from a lowland to a table-land), upon which "crop out" one or more Formations occurring in its locality.

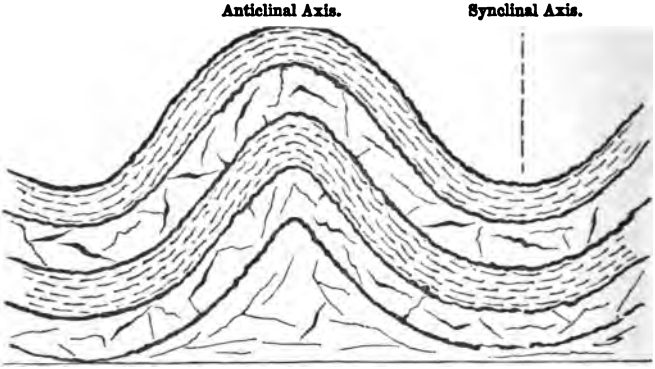
e. A modification of the causes which have produced the inclination of strata has in many cases resulted in the curvature of strata; which have been forced by lateral pressure sometimes into immense ridges and furrows, culminating occasionally in the elevation of ranges of mountains.

The summit line of such a ridge is called the "*anticlinal*"

line or axis—from the Greek words "*anti*," opposite, and "*clino*," I incline; meaning that the inclination is in opposite directions.

The line of furrow is called the "*synclinal*" line or axis—from the Greek words "*syn*," together, and "*clino*"; meaning that the inclines are towards each other.

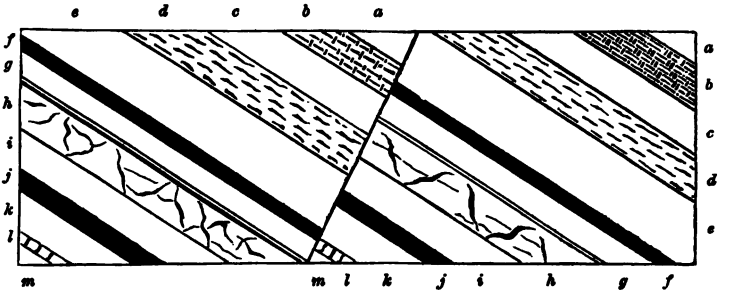
Fig. 1. *Anticlinal and Synclinal Axes and Curves.*



f. Certain displacements are frequent in Geological strata, which are called "*faults.*" Sometimes the rate of elevation or depression [see Section 18] is not uniform over a given area—portions of that area may rise or sink more rapidly than other portions: other phenomena (such as earthquakes, the shrinkage of underlying beds, etc.) also produce alterations in level. The result is, vertical or inclined fractures through the strata, and an interruption of their continuity: strata are brought into horizontal contact with other strata not normally upon the same level; but which, in regular vertical sequence, occur either above or below them. These dislocations (another name for the same thing) were first called "faults" by workmen in coal-mines, where they fre-

quently occur; because they found that, by them, coal-seams were frequently brought to an abrupt termination, and the miners were thus "at fault" to find coal.

Fig. 2. *Diagram of a Fault in Coal Measures—Beds much inclined.*



The beds *a*, *b*, *c*, *d*, etc., on the one side of the fault, are identical with the beds *a*, *b*, *c*, *d*, etc., on the other side of the fault.

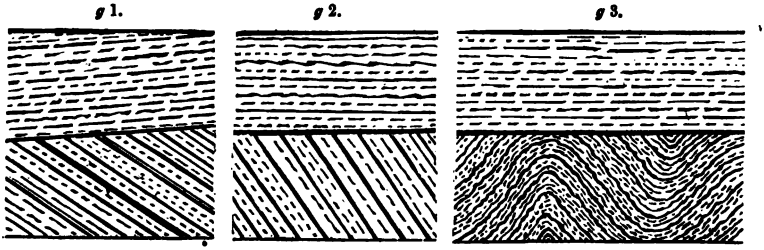
g. Another peculiarity in the position of beds is called "*unconformity*." This is—

g 1. When one group of beds overlies another group of beds at a different angle of inclination.

g 2. When a group of beds in a horizontal position overlies another group in an inclined position.

g 3. When a group of horizontal or inclined beds overlies a distorted group.

Fig. 3. *Examples of Unconformable Strata.*



This arrangement of beds has been produced, in either case, in this way—The lower groups originally were deposited as horizontal strata; afterwards they were thrown into an inclined position, or distorted, by internal movements of the Earth's crust [see Section 18, and Section 21, *d*]; and, having been more or less wasted by denudation, the superincumbent beds were deposited upon them by the processes described in Section 15.

The fact that groups of strata occur unconformably in a vertical sequence, is an evidence that, between the several periods of their formation, intervals of time of greater or less duration had passed, involving frequently a long intervening period of dry-land surface.

Geologists, therefore, accept "unconformity" of strata as a very cogent mark of distinction between Formations.

22. Springs the result of a certain disposition of beds.

a. Rain is the source of all water obtained upon land. Falling upon the surface, its water percolates the soil and the rocks beneath (if they be porous), and descends until it is arrested by a non-porous bed; where it accumulates in the overlying porous bed (which thus acts as a filter and a reservoir), until finding natural vent, it issues forth as *springs*.

b. The atmosphere slightly impregnates rain-water with carbonic acid, which thus charged, on encountering limestone or gypsum, dissolves and takes up a certain amount of lime, and appears in wells and springs as *hard water*.

c. Sometimes rain-water encounters in percolation decaying organic matter, becomes more highly charged with carbonic acid, and takes up a still larger amount of lime. Upon exposure, the acid flies off as gas, and the lime is precipitated

as carbonate of lime. Hence *petrifying springs* and the deposit (sometimes as rock masses) of *tufa* and *travertine.*

23. General deductions which have been drawn from the discoveries of Wm. Smith.

a. That the order of superposition or vertical sequence of sedimentary strata establishes their relative ages—those which are lowest being necessarily the most ancient, and those which are highest the most recent.

b. That their comparative mean thicknesses represent generally the comparative periods of time occupied in their formation.

c. That the contents of each bed indicate the conditions under which its formation (or deposition) took place.

24. The following great facts, as the results of these deductions, have been established:—

a. That the formation of the "crust" of the Earth occupied many and very extended periods of time.

b. That during those periods, the surface conditions of the Earth, and the nature and forms of its animal inhabitants and vegetable growth, underwent very numerous and complete changes.

c. That the several groups of strata form, as it were, museums, in which are preserved the remains of many of the animals which existed and of the plants which flourished during each mighty period of those strata's formation.

25. Advance made in the Science of Geology since the time of Wm. Smith.

Upon the foundation that he laid, have worked—the French Cuvier, and Buckland, Mantell, Sedgwick, Murchison, Lyell,

Phillips, Forbes, Ramsay, many other British Geologists, and a multitude of Foreign Geologists,—in every Quarter of the Globe, and nearly in every country of the World: so that, by their labours, has been upreared the wonderful structure of Geological Science as it now is; comprising—a knowledge of all classes of strata upon the Earth, their chronological order, and, for the most part, the areal position and extension of each, its mineral and chemical constituents, and its organic contents; and hence has been obtained an acquaintance with the grand series of physical phenomena by which the elaboration of the Earth's surface into its present perfect adaptation for all purposes of human civilized existence has been effected.

26. A Geological Map—

Is a map which shows, by means of different colours assigned severally to different Geological Formations, where each Formation occurs as the surface bed; and it thus indicates the general directions of the "dip" and "outcrop" and line of "strike" of every group of Formations occurring within the area of the map.

27. Peculiarities indicated by the Geological Map of this country.

a. The oldest Formations are situated in the West and North-West; the later Formations in the South-East and South; and those of intermediate age between, belting the country from the South-West to the North-East.

b. It may thus be seen that the general direction of the "dip" is to the South-East, of the "outcrop" to the North-West, and of the lines of "strike" from the South-West to the North-East.

[TO FACE PAGE 23.]

TABLE OF CLASSIFICATION OF GEOLOGICAL FORMATIONS,

WITH APPROXIMATE MAXIMUM THICKNESSES.

First Order of Division.	Second Order of Division—*into Systems.*	Third Order of Division—*into Groups.*	Maximum Thicknesses in Feet. 3rd Order.	2nd Order.	1st Order.	Life Periods.
QUATERNARY OR POST-TERTIARY.	Recent.					
	Post-Pliocene—	Post-Glacial	100	450	450	
		Glacial*	280			
		Pre-Glacial*	70			
	Pliocene *a*—	Newer†	2,000			CAINOZOIC, OR NEWER LIFE.
		Bunter	1,500			
PE.	Permian *j*—	Upper	600	4,450	26,650	
		Magnesian Limestone	850			
		Lower	3,000			

PART II.

1. SYSTEMATIC CLASSIFICATION of the whole Series of Geological Formations.

Tables of all have been compiled. The appended *Table** shows the whole number of Formations as classed under Three Orders of Division :—

a. Under the First Order, they are classed (commencing with the lowest and oldest beds) as—

A. The "UPPER PRIMARY" and "LOWER PRIMARY."

B. The "SECONDARY."

C. The "TERTIARY,"

D. The "QUATERNARY" or "POST-TERTIARY."

b. Under the Second Order of Division, they are separated into Sixteen Systems.

c. These, under the Third Order, are again divided into many Groups; each of which finally comprises few or many distinct Geological Formations.

2. Other Grand Divisions which this Table exhibits.

Besides the Three Orders of Stratigraphical Division, the immense periods of time which stratigraphical Formations indicate have been classed into Three Great Divisions, or *Life Periods* :—

a. The "*Palæozoic*," or Old Life,—the lowest and oldest of the three; the Life-Forms of which, as a series, are entirely and the most dissimilar to those now existing. The lowest,

* See Folded Table.

and therefore oldest, Formation of this Life-Division constitutes a Sub-Division—the "*Protozoic*," or First Life.

b. The "*Mesozoic*," or Middle Life,—later in the succession of time; the Life-Forms of which, as a series, more nearly resemble those now existing, although (with the exception of one or two genera and some microscopic organisms) still of entirely distinct kinds.

c. The "*Cainozoic*," or Newer Life,—the last in the succession of time; the groups of Life-Forms of some of the earliest Formations of which include some forms now existing: the proportionate number of such existing forms increase in every successive group of Formations, until, in the latest Formation, the Life group consists almost wholly of existing forms. The "Cainozoic" Division, therefore, has been made to include the "Recent" or existing Life Period.

A. Primary Strata—Palæozoic Life Period.

3. The *first trace* of Animal Life—

Has been found in the lowest (and therefore, as before stated, the *oldest*) Formation yet determined,—the Lower Laurentian of Canada,—hence termed the "Protozoic" or First-Life Sub-division. This is characterized by the presence of a fossil which represents, as it were, the *advent* of life upon the Earth, and which presents itself in the very humblest and least organized phase of animal life. It belongs to the class "*Rhizopoda*," or "root-footed,"—from the Greek "*rhiza*," a root, and "*podes*," feet.

a. It has been called the "*Eozoon Canadense*"—"*Eozoon*," the dawn of life, from the Greek words "*eos*," dawn, and

"*zoe*," life, and "*Canadense*," from Canada, the country in which (in 1859, by Sir Wm. Logan) it was first discovered.

b. So low a form of life was this *first* living thing, that it was almost entirely devoid of the structure and the functions which we are accustomed to associate with the idea of a living animal. It was a "gigantic" member of a group which existed in many subsequent Formations, and is still existing, as the lowest group of animal Life-Forms, the *Foraminifera**; the various species of which, with some exceptions, are of microscopic minuteness. The *Eozoon Canadense* was allied to the living Foraminifera *Carpenteria* and *tinopus*: it had a chambered calcareous skeleton, grew in tiers or layers one over another, and its chambers were connected by "stolons" or passages. Its habits resembled that of some "prolate" (or laterally-spreading) Corals now living, and like them formed layers and masses of limestone.

c. The *Eozoon* was also recognized, in 1863, by Dr. Gümbel of Munich, in Bohemia and Bavaria, in beds of great thickness ("50,000 French feet"), equivalent to the American Lower Laurentian (18,000 English feet in thickness); and it is said to have been found also in Finland.†

d. The *Eozoon Canadense* seems to have originated in, and to have died out during, the period of the Laurentian System; and, as thickness of strata represents approximately an equivalent passage of time, (unless we accept the unlikely suggestion that *life* originated and ceased during this period, remained for long ages extinct, and was re-initiated at an after epoch), we are led to the conclusion that the *Eozoon Canadense* may have lived upon the Earth, as its solitary Life-Form, for a period nearly equal to the sum of the vast

* See forward, pp. 73, 74.

† Murchison—*Siluria*, 4th edit., pp. 373 and 550; and *Journal of Geological Society*, 1863, p. 357.

periods of time represented by the slow sedimentary formation of all the strata comprised in the Secondary, the Tertiary, and the Post-Tertiary Divisions; or more than one-fifth the sum of all the periods represented by aqueous strata.*

4. The UPPER LAURENTIAN System—

Occurs in Canada and the State of New York, in Bohemia and Bavaria, in Sutherland and the Western Islands in Scotland, possibly in the Malvern Hills in England, and in Ireland. It reaches a thickness of 12,000 feet in America, and "35,000 French feet" in Europe.†

No organic remains have been found in this System.

5. The CAMBRIAN System—Lower Division.

a. At Bray's Head at Wicklow in Ireland, in slaty beds, perhaps older than the lowest slate beds of Wales and Westmoreland, were discovered, 20 years ago, certain Life-Forms (not more organized than the Laurentian *Eozoon*), consisting of two species of a kind of *Hydrozoa*, and which were named "*Oldhamia antiqua*" and "*Oldhamia radiata.*" ‡

b. Doubts have latterly been raised as to these being Life-Forms at all, and suggestions have been severally offered that they are of vegetable origin, and again only accidental wrinklings of the thin laminæ of the matrix.

c. Until the discovery of the *Eozoon Canadense*, the *Oldhamia antiqua* and *O. radiata* were considered to be the most ancient of all Life-Forms; and, as in the case of the *Eozoon Canadense*, they both originated and died out during the period of the Formation in which they are found.

* *Vide* Sir Wm. Logan, quoted in Lyell's *Student's Manual*, pp. 491–2.

† Murchison—*Journal of Geological Society*, 1863, p. 357.

‡ "*Hydrozoa*" is derived from the Greek "*hydor*," water, and "*zoon*," an animal; "*Oldhamia*" from the name of the late Professor Oldham, the discoverer. "*Antiqua*" and "*radiata*" are Latin words—the former meaning "ancient," and the latter "radiated," from the form of that species.

d. There is little doubt that, during both the period of this Formation and the period of the Laurentian, some minute forms of *vegetable* growth (probably microscopic, and not to be detected in a fossil state) did exist, and furnished food for these earliest of mundane Life-Forms.

6. Life-Forms occurring in beds successively later in age than the bed last mentioned; but still comprised in the Lower Cambrian group.

a. Higher and subsequent beds exhibit progressively Life-Forms more various in kind, more organized in structure, and individually more numerous.

b. In the bed immediately above the last, have been found fossil indications of no less than five small *annelids* or sea-worms, and an obscure *crustacean*,—constituting the earliest appearance of animals of these two classes.

c. In beds little subsequent to these, have been found in North and South Wales, in Bohemia, and in America, successively increasing numbers of Life-Forms,—still advancing in the character of their organization, and in the variety which they assume. They consist of more than 40 distinct kinds, and comprise several *annelids*, *bivalves* of more numerous genera and species, *cephalopods* (from the Greek words "*cephale*," the head, and "*podes*," feet—head-footed animals, represented in our modern seas by the Nautilus, Cuttle-fish, Octopus, etc.), and a peculiar *crustacean* called a *Trilobite* (from the Greek "*treis*," three, and "*lobos*," a lobe, indicating its trilobed form), of which several species from these beds have been defined.

d. Until quite lately, these beds were deemed to be almost devoid of fossils; and there is every reason to believe that

in the periods which these beds represent in time, the forms referred to first made their appearance in the animal sequence of the Earth's Geological history.

e. The sandstones of this Formation are occasionally ripple-marked, and we have evidence that the sea-shore sand was often (even in this most remote era) left dry by the fall of the tide: these sandstones are often sun-cracked, and are sometimes even pitted by rain-drops, so as actually to indicate the direction of the wind at the time the shower fell.

7. The Fauna of the Upper Cambrian.

Life-Forms still rapidly increase in number and variety with each succeeding bed; but no form of so distinctive a character as to need notice here has been found.

8. The SILURIAN System.

a. Several new orders of Life-Forms here make their first appearance, including—many *Corals*, numerous *Graptolites* (remotely allied to Corals, but of a lower organization, and which died out during the Silurian era), univalves or *gasteropods*, several genera of *cephalopods*, a few *Star-fishes*, *Crinoids* (or sea-lilies), and a genus allied to *Echinus*.

b. In the Upper Silurian beds also, *vertebrate fishes* first appear—a great advance in animal organization. These fishes had a peculiar formation of tail called the "*heterocercal*"—from the Greek words "*heteros*," different, and "*kerkos*," a tail; meaning that the two lobes of the tail were dissimilar, the vertebral column extending into and to the end of the upper lobe of the tail. This was the characteristic of all fishes living during the whole of the Palæozoic

Life-Period; but the peculiarity only occurs in the present day in Sturgeons, in the Bony Pike of America, and in the Shark tribes.

c. Trilobites are the most characteristic Life-Forms of the Silurian rocks. They were the scavengers of and dominated those ancient seas. They appeared in the Cambrian period, flourished through the Silurian period, and died out in the subsequent Carboniferous period.

9. The DEVONIAN and OLD RED SANDSTONE System.

a. The beds of this System consist partly of Marine and partly of Freshwater strata: the former in this country are mainly situated in Devonshire; the latter in Scotland, Herefordshire, and South Wales, having been there deposited in lakes on a scale nearly equal to that of the existing American lakes.

b. The *marine fauna* consists of a series of heterocercal *fishes*, three or four species of *Trilobites*, a magnificent series of *Corals*, with bivalve and univalve *mollusca*.

c. The *freshwater fauna* includes numerous *fishes*, some of peculiar character, covered with a shelly armour, comparable to the carapaces of crustaceans,* but having little affinity with those forms: the more remarkable genera are the *Pterichthys* or "winged fish," and the *Cephalaspis* or "buckler-headed" fish. This fauna comprises only one shell, an *Anodonta*, allied to the Mussel of our rivers and lakes.

d. The most characteristic fossil, however, is a huge *crustacean*, sometimes nearly six feet long and a foot broad, remotely allied to the Cray-fish of our rivers. It has been named "*Pterygotus*." An allied genus called "*Eurypterus*," and other genera of smaller size, also occur. Even their

* Lyell's *Student's Elements*, pp. 441–2.

ova-sacs have been found. These extraordinary forms appeared first during the later Silurian period, and died out during the early Carboniferous period.*

The *flora* consists of some plants chiefly allied to *ferns*.

10. The CARBONIFEROUS System.

a. The lower beds, consisting of limestones mostly of coarse texture, contain numerous "sea-lilies" or (*Crinoids*), some of new genera; also *fishes* having palatal teeth fitted for feeding upon shell-fish, many new *univalves*, *bivalves*, *brachiopoda* (including the genus *Productus*, some species of which are very large), the *Nautilus* and other forms (*Goniatites*) foreshadowing the Ammonite, and *Trilobites*, which died out in this period.

b. The Coal Measures are characterized by many forms of animal life now for the first time seen—*insects* (a kind of Grasshopper, several kinds of Beetles, Crickets, Centipedes, an insect allied to the Spider, etc.), a *land Snail*, and *reptiles allied to fishes*,† *Archegosauri*.‡

c. The Coal Measures are chiefly remarkable for their wonderful *flora*—consisting of colossal *ferns* and *palms*, *Equisetites* (or the horse-tail plants), tree-like *mosses*, and some coniferous plants, remotely allied to the Araucaria: and from these has all true coal been derived.

11. The PERMIAN System.

a. The Lower Permian beds have an aggregate thickness of 3,000 feet. In this country, they occur chiefly in Durham, Yorkshire, and Warwickshire, and are mainly characterized by their plant-remains. In the lowest beds are some few

* Woodward—Monograph on *Merostomata*, *Palæontological Society*, 1866. † Owen's *Palæontology*, p. 195.

‡ Greek "*archegos*," beginning, and "*sauros*," a lizard; primordial lizards.

plants found also in the Coal Measures; but in the higher beds these successively disappear, until the flora is entirely distinct. Organic remains are generally absent, but worm-tracks and foot-prints of *reptiles* are found.

b. The Middle Permian or Magnesian Limestone (deriving the latter name from the mineral character of many of its beds) has an aggregate thickness in this country of about 850 feet, being chiefly developed in the North-East of England. It is very fossiliferous, its most remarkable Life-Forms being those of *Corals* and *fishes*, the latter comprising numerous genera and species, but all having the heterocercal tail.

c. The Upper Permian has its chief thickness in Cumberland (about 600 feet). It consists of red sandstones and clays, with occasional beds of gypsum. It is not noticeably fossiliferous.

d. The fauna of the Permian Formations in this country numbers 147 species, of which 77 are mollusca, including 25 *gasteropods* and only one *cephalopod*, a Nautilus. Of these, none lived on into later periods, and of only one group of bivalves (*brachiopods*) had species existed in older times.

B. Secondary Strata—Mesozoic Life Period.

12. The Triassic (or New Red Sandstone) System.

It was stated in the last Section that none of the Life-Forms of the Permian period continued on into subsequent periods. The few Life-Forms which occur in the lowest Triassic beds as a group are sufficiently distinct from the Life-Forms which had preceded them to mark a well-defined

line of separation between the Palæozoic and Mesozoic Life-Periods.

Of the three great Triassic Divisions—the Keuper, the Muschelkalk, and the Bunter,—only the first and the last occur in this country.

a. The Bunter is characterized by the occurrence for the first time of indications (by foot-prints only) of a large species of *reptile* of the Batrachian Order (remotely allied to the toad), which, from the likeness of those prints to the human hand, has been called "*Cheirotherium*"—from the Greek words "*cheir*," the hand, and "*therion*," a wild animal; also, in its lowest beds near Bristol, two genera of *reptiles* (perhaps terrestrial or partially amphibious) allied to the less ancient *Dinosauria* (from the Greek "*deinos*," terrible, and "*sauros*," a lizard), and which in some particulars of structure were allied to birds. This Formation has a thickness of 1,500 feet in Warwickshire, and has there been found to include trunks of trees 18 inches in diameter, exhibiting the rings of annual growth.

b. The Keuper attains a thickness of 3,450 feet in Cheshire, and is remarkable for the immense deposits of *salt* which it contains in that district. The Formation has yielded—a few land *plants*, *cephalopoda* nearly allied to the Ammonite (foreshadowing the advent in the succeeding Formation of that multiform genus), and *fish*; also traces and remains of numerous amphibious *reptiles*, including a Batrachian form, which, from the peculiar structure of its teeth as seen in section, has been called by Professor Owen "*Labyrinthodon*" (from the Greek "*labyrinthos*," a labyrinth, and "*odous*," a tooth); a form having a small bird-like skull and jaws without teeth, called "*Rhynchosaurus*" (from the

Greek "*rhynchos*," a beak, and "*sauros*," a lizard); and a terrestrial *reptile* closely allied to a reptile still living in New Zealand.

c. It is to be noted that, in the few *fishes* found in the Trias, the "*homocercal*" form of tail is for the first time introduced, and is the prevailing form in all subsequent Geological periods. Sir Chas. Lyell says, "The *homocercal* fish, which comprise almost all the 9,000 species at present known living, have the tail-fin either single or divided; and the vertebral column stops short, and is not prolonged into either lobe." "*Homocercal*" is derived from the Greek words "*homoios*," like, and "*kerkos*," a tail; meaning that the two lobes of the tail are alike.

d. The most remarkable remains found in the Keuper, however, are the teeth of a small *Marsupial mammal*, called "*Microlestes*"—from the Greek "*mikros*," little, and "*lestes*," a robber, as belonging to the "rapacious" group of Marsupialia. These constitute the oldest known traces of mammalian life upon the Earth, and present the lowest form of mammalian life, the young of which are produced in an immature condition, and matured in a pelvic pouch—hence "*Marsupialia*," from the Latin "*marsupium*," a pouch. The Marsupialia of the present time only exist in Australia, a few of the Indian islands, and America.

e. In America, foot-prints of *birds*, some four times the size of those of the existing Ostrich, have been found in beds of the Triassic period. They are doubtless those of large wingless or flightless birds, and are the earliest traces of the existence of any kind of bird which have yet been discovered.

f. While in the German Muschelkalk (the intermediate

Formation of the Trias), the abundant fossils are all of marine origin, no traces of marine life have been detected in the over- and underlying Keuper and Bunter of this country: these Professor Ramsay considers to have been the deposits—the former of salt lakes, like the Caspian and Dead Seas, and the latter in lakes variably of salt, brackish, and fresh water.*

13. The Rhætic Beds.

These beds are also called—by the Government Geological Survey, the "Penarth Beds," from Penarth, near Cardiff, where they attain a considerable thickness; and by Dr. Wright, the "*Avicula contorta* Beds," from the prevalence of that fossil in the principal bed of the group.

a. The Rhætic beds are regarded as "*beds of passage*" between the Triassic and the Liassic Systems.

It cannot be conceived that there could have been a point in time at which the period of any System or Formation definitely ceased and the period of any succeeding System or Formation as definitely commenced. One must have merged into the other, and Life-Forms have been gradually transmuted into or superseded by other Life-Forms, during a connecting period of longer or shorter duration; and such connecting or transitional period must have had a stratigraphical representative in "*passage-beds*," either somewhere remaining or lost by denudation.

The continuity of the Cambrian and the Silurian Systems is so complete that the exact line of separation was in early days a matter of dispute between Sedgwick and Murchison,

* *Physical Geology of Great Britain*, 3d Edit., Table, p. 26; and *Journal of Geological Society*, 1871, pp. 189–241.

and is even now under discussion. The passage of the Silurian into the Devonian, of the Devonian into the Carboniferous, and of the Carboniferous into the Permian Systems, in each case, is partially indicated (but in a greater or less degree) by the continuing on of some Life-Forms of the earlier System into the succeeding System, and by the commingling for a time of the Life-Forms of both; which Life-Forms would thus occupy, as it were, a kind of "border-land" between the two Systems.

No indication of a "passage" of the Permian System into the Triassic System has yet been discovered; but that of the Triassic into the Liassic is completely represented by the Rhætic beds. "Passage-beds," and more or less distinct indications of "passage," and some abrupt breaks, occur between subsequent Systems and Formations, which will be referred to in Sections to come.*

b. The fossils of the Rhætic beds are marine. The most characteristic of the *mollusca* is the bivalve *Avicula contorta*, referred to above. Some of the species are continued on into the Lias. *Marsupial* teeth have also been found in this Formation. The Rhætic group is chiefly allied to the previous System by the contents of a bone-bed or *breccia* (from the German "*brecken*," to break, the bed being made up of fragments), which occurs in Devonshire, exposed in cliffs bordering the Bristol Channel; which contents consist

* To establish doubtful "passage-beds," and to discover "passage-beds" where none are now known, would be good work for rising Geologists; for, by this means, "the fragmentary character of the Geological record" (as spoken of by Sir Chas. Lyell) would be gradually if only partially repaired, and an approach made to that "*continuity*" which was the text-word of Mr. Justice Grove in his Presidential Address at the Meeting of the British Association at Nottingham in 1866.

of the remains of *saurians* and *fishes* common to the intermediate Division of the Trias, the marine Muschelkalk of Germany.

14. The Liassic System.

The Lias, although unbroken by any plane of unconformity throughout the entire vertical series of its numerous beds, has been divided into three groups—the *Lower Lias* Clay and Limestone, the *Middle Lias* or *Marlstone* Rock-bed and Sands, and the *Upper Lias* Clay. These stretch, as a constant series, in a belt across England, from the Dorsetshire coast on the South-West to the Northernmost point of the Yorkshire coast on the North-East.

a. The *Lower Lias* is characterized by the first appearance of several new forms of *mollusca*, such as—*Lima gigantea, Gryphæa incurva, Avicula cygnipes* (swan-footed), *Hippodium ponderosum*, etc.; also by a peculiar *Crinoid* (from the Greek "*krinos*," a lily, and "*eidos*," form—lily-formed, or like a lily), having innumerable tentacular arms, and named therefore *Extracrinus Briareus*, from the classical hundred-armed Titan Briareus.

b. In the *Middle Lias*, occurs commonly a large bivalve shell, having bold "*costæ*" or ribs, and called *Pecten equivalvis*, the two valves being nearly uniform; also a band of closely compacted bivalve shells of the class *Brachiopoda* (Gk. "*brachion*," an arm, and "*pous*," a foot—arm-footed), called *Rhynchonella tetraëdra* (Gk. "*rhynchos*," a beak, "*tetra*," four, "*ëdra*," a base or seat, meaning four-sided); and a small *Star-fish*, having five attenuated and tortuous rays.

c. In the *Upper Lias*, the advent of *Oysters* proper occurs.

It has yielded also, in the neighbourhood of Northampton, a peculiar clawless Lobster, named by Mr. Woodward *Peneus Sharpii*; and it is remarkable that this genus still lives in the Mediterranean. The *jet* of Whitby and Scarborough (bituminized fossil wood) is found in the clay of the Upper Lias.

d. At the base of the Upper and Lower Lias Divisions respectively, occurs a bed which is crowded with the remains of *insects*, small fish, and crustaceans, ferns, cycads, and leaves, brackish and freshwater, and in some places marine shells. The insect remains have been found to include several genera and many species of Beetles, Grasshoppers, Dragon-flies, and May-flies.

e. The Liassic beds are in the main marine deposits; some, however, are estuarine; and the Insect-beds certainly are almost if not entirely of freshwater origin.

f. The three Divisions of the Lias have together yielded more than 1000 species of *mollusca*, including some 280 *cephalopods*, of which nearly 200 are *Ammonites*, the remainder consisting (with one exception) of various species of the *Nautilus* and *Belemnite*. The *Ammonite* and *Belemnite*, as definite *genera*, make their first appearance in the Lower Lias. The different species of Ammonites have been found severally to have so limited a vertical range that they have been utilized for the division of the Liassic beds into "*zones*"—the Lower Lias into *seven* zones, and the Middle Lias into *five* zones: the Upper Lias Clay, consisting of *one* zone only, is characterized by six species of Ammonites.

The word "*Ammonite*" is derived from the name of the Lybian deity Jupiter Ammon, on account of its likeness to the curled ram's horns with which the head of the latter was furnished. The word "*ammon*" is said to be Egyptian.

"*Nautilus*" is derived from the Greek "*nautilos*," a second name given by Aristotle to the shell *Argonaut*, a word derived from the Greek "*argo-nautes*," a sailor of the ship Argo; because this cephalopod was mistakenly thought to float upon the surface of the sea with its arms dilated for sails, like a ship. The Nautilus is represented by a few species still existing in tropical seas.

The word "*Belemnite*" is derived from the Greek "*belemnon*," a dart, on account of the shape of the internal shell, the only portion of the animal which has been preserved. The Belemnite has a near affinity to the existing Cuttle-fish.

Fishes abound in the Lias, as many as 120 species having been identified in the British beds alone. These are almost entirely *homocercal* in character, and have a generic affinity to those of the succeeding Oolitic System.

The Liassic period was the era of colossal *reptiles*. Its seas teemed with *Ichthyosauri* ("fish-lizard"), *Plesiosauri* ("like a lizard"), and *Teleosauri* ("quite a lizard"). The last was a Crocodile, having affinity to the Gavial, or long-snouted Crocodile of the Ganges. A kind of *flying lizard*, *Pterodactylus* (from the Greek "*pteron*," winged, and "*dactylos*," a finger; meaning wing-fingered), is more rarely found. The wings of this flying saurian consisted of a membrane extending from a fore-finger (which was elongated so as often to exceed the length of the neck and body of the animal) to the hind leg and tail, just like the wing of a Bat. The existence of all these genera of reptiles apparently commenced in the Liassic period.

15. The SUPRA-LIASSIC or MIDFORD SANDS—*Passage-Beds*.

a. In these Sands are commingled fossils characteristic

of the under-lying Upper Lias Clay (*Ammonites opalinus, A. insignis, A. radians*, etc.), and fossils characteristic of the over-lying Inferior Oolite Formation (*Pholadomya fidicula, Gervillia Hartmanni, Hinnites abjectus, Myoconcha crassa*, etc.), together with some peculiar to the Sands themselves, such as *Rhynchonella cynocephala* (Gk. "dog-headed"): they are held, therefore, to be *passage-beds* between the Upper Lias and Inferior Oolite, and to be the "stratigraphical representatives" of a transitional period which connected, and constituted the *continuity* of, the great periods of the Liassic and Oolitic Systems. [See Part II. Section 13.]

b. These beds have their greatest thickness in Dorsetshire, Gloucestershire, and Somersetshire; in which counties they first attracted the attention of Geologists: they were designated by the late Professor Phillips (who first described their transitional character), the Midford Sands, from the Midford Valley in the last-named county, in which they are well shown.

These Sands have their equivalents also in Lincolnshire and Yorkshire, and are importantly represented in the lower portion of the ferruginous beds of the Northampton Sand. They are of marine origin.

16. The Oolitic* or Jurassic System.

* The term "Oolitic" was originally applied to some of the beds of this System on account of the peculiar structure of their stone. A polished section of such stone shows that it consists of egg-shaped grains (formed of minute *nuclei* of silicious particles or shell-fragments enclosed in numerous concentric calcareous films) embedded in a calcareous matrix. This term, so appropriate to such beds, came to be applied to the whole System, comprising beds of sand, clay, shale, marl, etc.; but as to these it is a misnomer.

The Oolitic System is divided into the *Lower*, *Middle*, and *Upper*.

A. The LOWER DIVISION comprises—the *Inferior Oolite*, the *Fuller's Earth*, the *Great Oolite* (including the *Stonesfield Slate* and equivalent Clays as its base, and beds equivalent to the *Forest Marble* and *Bradford Clay* of the West of England as its upper portion), and the *Cornbrash*.

17. The *Inferior Oolite*—

In the South-West of England, attains a thickness exceeding 250 feet: it is wholly marine, and is only ferruginous in a thin band which immediately overlies the passage-beds of the Supra-Liassic Sands. It consists of numerous beds, which differ much in mineral character, and comprise variously strata of sand, sandstone, grit (a coarse sandstone), rag (a coarse shelly stone), flaggy limestones, soft calcareous (or limey) marls, pisolitic limestone (consisting of pea-like grains—"*pea-grit*"), and beds of Oolitic limestone. In consequence of the persistent presence of particular species of Ammonites through certain ranges respectively (as in the Liassic System), Dr. Wright has divided these beds into the *Ammonites Murchisonæ* zone, the *A. Humphresianus* zone, and the *A. Parkinsoni* zone.

a. In the Midland Section of the Inferior Oolite (the typical development of the lower part of which occurs in Northamptonshire, and of the upper part in Lincolnshire), these beds assume very different conditions. In the Lower Division of the *Northampton Sand* (the lowest beds of the Inferior Oolite throughout this area), occur the now famous ironstones of Northamptonshire. These represent a shallow sea of varying depth, occasionally littoral (as shown by a

band of ripple-marked slabs), and afford evidence of still further shallowing, until their conformable junction with an overlying estuarine deposit (designated by Mr. Judd the "*Lower Estuarine*"). Both Formations are traceable from Oxfordshire, through Rutland and Lincolnshire, into Yorkshire, where their equivalents are to be recognized—the former in the ferruginous beds of *Glaizedale* and the *Dogger*, and the latter in the *Lower Plant Shale* of the same districts.

b. In the Northern Division of Northamptonshire, a series of marine limestone beds, overlying the Lower Estuarine, appears—at first as a very thin deposit, but rapidly increasing in thickness in a North-Easterly direction, until in Mid-Lincolnshire it attains a thickness exceeding 200 feet. It passes on for some miles into Yorkshire, where it thins away. This Formation has been called the *Lincolnshire Limestone*, and comprises various marly, shelly, and oolitic beds, which yield some of the most anciently quarried and finest building-stones in England. It has no known equivalent elsewhere, although it is nearly synchronous with (but perhaps a little later than) the limestones of the *Ammonites Humphresianus* zone of the West of England.

c. The Lincolnshire Limestone is based throughout the greater part of its area in Northamptonshire by a calcareo-silicious bed; which, upon exposure to frost, splits in the planes of its fine *laminæ*, and is called *Collyweston Slate*, from the locality in which it is chiefly excavated: it is extensively used for roofing.

d. In Yorkshire, occurs a "*Grey Limestone*," of marine origin; formerly considered to be Great Oolite, but latterly by its fossils determined to be Inferior Oolite: it is pro-

bably a little higher in the scale than the Lincolnshire Limestone.

e. The Inferior Oolite beds in the Western and Midland districts are characterized by the bivalves *Terebratula fimbria, Rhynchonella spinosa,* and *Pholadomya fidicula.*

e 1. The Northampton Sand has yielded many forms of *mollusca* previously unknown; also a beautiful solitary specimen of a *Star-fish,* which has been named by Dr. Wright *Stellaster Sharpii*: another form of *Stellaster* has been found in a nearly equivalent bed in the South of France; and these are the earliest examples of this genus which have been discovered. The scutal plate of an unrecognized species of *Teleosaurus* has been found, as have also, in two localities, a tooth and pelvic bones of two individuals of the *Megalosaurus* (from the Greek "*megalos,*" great), a huge carnivorous land or amphibious lizard, the osseous structure of which in some particulars was remotely akin to that of birds.

e 2. In the Lower Estuarine, a plant-bed (showing the plants as growing *in situ*) constitutes the only organic remains yet discovered. This plant-bed, in its extension into Yorkshire, assumes the character of a lignite or impure coal.

e 3. The Collyweston Slate is very fossiliferous in patches, the *mollusca* being wholly marine, and mostly of the usual Inferior Oolite character. One beautiful winged *bivalve, Pterocera Bentleyi,* is tolerably abundant, although only two specimens have been found in the Limestone above, and it is unknown in other localities. A unique *Star-fish* has been found in this slate, named by Dr. Wright *Astropecten Cottes-woldiæ, var. Stamfordensis,* which is not known to occur elsewhere.

e 4. The Lincolnshire Limestone is remarkable for a very shelly bed, called "Barnack Rag," which formerly yielded a very durable building-stone, having been quarried by the Romans. The Formation has yielded a fine series of *mollusca* (mostly of Inferior Oolite types, commingled with Great Oolite forms, not known to occur in so low a bed elsewhere), some remarkable *Corals* of new forms, teeth of *fishes* and of *Teleosaurus*, patches of *Fern* (*Polypodites Lindleyi*), and a fine single specimen of *Aroides Stutterdi* (the spadix or spike of a plant remotely allied to the *Arum* and to the "Lords and Ladies" of the hedges), which has never before been found in so old a bed.

e 5. The most remarkable fossil of the Grey Limestone of Yorkshire is the largest form of *Belemnite* known—*B. giganteus*.

18. The *Fuller's Earth* is an argillaceous bed of about 70 feet in thickness, which comes in between the Inferior Oolite and the Great Oolite, but only occurs in the West of England. It has yielded about 70 species of marine *mollusca*; of which only three are univalves (or *gasteropods*, "belly-footed"), and seven or eight *cephalopods*.

19. The *Great Oolite*.

a. In the South-West of England, the Great Oolite consists in its lower portion of thick beds of Limestone. Some are famous as building-stone under the name of the "*Bath Oolite*": others contain several species of *Corals*, one (*Calamophyllia*) occurring in large masses, the growth of which must have taken "many centuries."* These beds alter greatly

* Lyell.

in Gloucestershire: the deep-sea deposit becomes a shallow sea-deposit, the total thickness greatly diminishes, and the strata instead of being thick-bedded are thin and laminated: they thicken again, however, in the neighbourhood of Cheltenham. They are exceedingly shelly, more than 400 species of mollusca having been identified; of which 224 species are *gasteropods*, and comprise no less than 50 carnivorous species, a group having no analogue in older Formations.

b. Above the Limestones, is a Clay Formation, which sometimes assumes in some of its beds the character of an argillaceous limestone; which, taking a good polish, and being rendered ornamental from the shells which it contains, has been locally called the "*Forest Marble*." Some beds consist of thin calcareous "tilestones," used as roofing-slates, which bear various trails and foot-prints of small *crustacea*, etc. Similar thin laminæ, thus impressed, occur in equivalent beds in Northamptonshire. In the neighbourhood of Bradford, Wilts, the Formation occurs as a thick clay, and has there received the name of that town: it is characterized by the occurrence of peculiar *Crinoids* (*Apiocrinus*, "the pear-Encrinite"), remarkable as occurring in clay.

The Great Oolite series extends into Oxfordshire, and thence, nearly North, through Northamptonshire, East Rutland, into Lincolnshire.

c. It is based in Oxfordshire by the *Stonesfield Slate*, an arenaceous thinly-laminated limestone, much like the Collyweston Slate described in the last Section. Its organic contents are remarkable: the *mollusca* and *fish* are marine, while several species of *reptiles*, of the genera *Plesiosaurus*,

Teleosaurus, Pterodactylus, etc., are more or less so; but these are associated with wood, Fern and Palm fronds, fruit of various *coniferæ,* fragments of *Aroides Stutterdi* [see last Section, *e* 4], and other plants; also the wing-cases of Beetles, a beautiful wing of a Butterfly (never before found in so old a bed), and many *insects*: but of the terrestrial remains, the most notable are those of three genera and four species of *Marsupial mammals,* quite distinct from the *Microlestes* of the Trias and from the Rhætic genera [Pt. II. Secs. 12, *d,* 13, *b*]; and which, until the discovery of the latter, were considered to be the earliest form of Mammalian life.

These organic remains indicate that this bed was deposited at or near to the mouth of a large river. In tracing it Northwards, we find that it loses its *marine* character, and assumes more and more of the character of an *estuarine* deposit: it traverses Northamptonshire, East Rutland, passes into Lincolnshire, and is probably ultimately represented by the Upper Plant Shale near Scarborough, a purely *fresh-water* bed, as evidenced by the abundant presence of the great fresh-water Mussel *Anodonta.* We are thus enabled to trace, for some 200 miles, the nearly North and South course of a river of the Oolitic period, from its freshwater condition, through its estuary, into the sea.

a'. The *Limestone* beds traverse Oxfordshire, become again attenuated in Northamptonshire, and finally thin-out in Lincolnshire—no equivalent being found in Yorkshire.

The beds in these counties are generally very rich in organic remains—more than 200 species of *mollusca* have been identified, and various *cephalopoda, echinodermata,*

crustacea, fishes, reptiles, Corals, and *plants.* Of these, the most noticeable are—large *Nautili,* several beautiful species of *Acrosalenia,* a small *Star-fish* (*Ophiurella*), a small *Lobster* (allied to *Eryma elegans*), numerous teeth of *fish* and *crocodilia,* and a fine cone of a *pandaceous fruit* (*Kaidacarpum Ooliticum*).

b'. The overlying *Clay* (=*Forest Marble* and *Bradford Clay*?) is very thin, and occurs only in patches, in Oxfordshire, thickens again in Northamptonshire, and disappears in North Lincolnshire.

This Clay, in Oxfordshire, Northamptonshire, and Rutland, (probably of mixed marine and estuarine origin), has yielded remains of more than one species of a colossal land and herbivorous *Lizard, Ceteosaurus* ("Whale-like Lizard," a name given by Professor Owen in allusion only to its vast size). The wonderful although imperfect skeleton in the Oxford Museum, so patiently collected by Professor Phillips, is the largest known example of a saurian of any species. Its probable length exceeded 60 feet, its height 10 feet, and its width through the fore-part 6 feet.

20. The *Cornbrash.**

This Formation consists of a thin bed of argillaceous limestone, rarely more than about 15 feet thick: it is very rich in marine and fossil remains, of which only *Terebratula Bentleyi, T. lagenalis, Trigonia Cassiope,* and *Chemnitzia vittata,* are sufficiently distinctive to be noted here.

The Cornbrash was first defined as a Geological Formation in the South-West of England: it extends over nearly

* A local name in the West of England, derived from the fact that this rock, after disintegration, makes good soil for the growth of corn.

the whole of the Oolitic area, even into North Yorkshire, sometimes occurring in wide-spread fields, and sometimes as patches capping high lands. With regard to this fact, Jukes, in his *Manual*, remarks, "It is singular that the little insignificant-looking band called Cornbrash continues lithologically and palæontologically the same as in the South of England, while so great a change takes place in the more important beds below."

B. The MIDDLE DIVISION comprises three Formations, the *Lower* consisting of the *Kelloway Rock*,* the *Middle* of the *Oxford Clay*, and the *Upper* of the *Coral Rag* and *Calcareous Grit*.

21. The *Kelloway Rock* occurs in the South-West of England as an arenaceous limestone in lenticular masses, 8 or 10 feet thick, embedded in the Oxford Clay; as a member of which it was formerly classed. In the Midland districts, however, it is always at the base of the Clay; and in Yorkshire, in the same position, it has thickened to 30 feet: moreover, of 143 species of *mollusca* 34 only, and of 52 *cephalopoda* 15 only, are common to the Oxford Clay. The Kelloway Rock, therefore, is now classed as a distinct Formation. Its most distinctive fossils are—*Gryphæa bilobata* and *Avicula expansa*. Two beautiful *Star-fish* (*Astropecten Orion* and *A. clavæformis*—Latin, "club-shaped") have also been found in the Kelloway Rock of Yorkshire.†

* From Kelloway, Wilts, where it was first observed.

† See Dr. Wright on *Asteroidæa*, in *Palæontological Society's Monographs*.

22. The *Oxford Clay* is a dense Clay having a thickness of some 600 feet. It derives its name from its being the sub-surface Formation of the plain upon which Oxford stands: but it stretches from Weymouth in Dorsetshire to a point North of Scarborough in Yorkshire; it constitutes the sub-surface bed of nearly the whole county of Huntingdon, and sublies the alluvial beds of the great flat of the Huntingdonshire, Cambridgeshire, and Lincolnshire Fens.

The fossils of this Formation are very numerous as to species, and very abundant. *Mollusca* are less plentiful than *cephalopoda*: of *Ammonites* there are many species; some of which have with the shell been perfectly preserved in thinly laminated clays at Christian Malford, and others in the Fen beds, beautifully irridescent, from *iron-pyrites*: of *Belemnites* one species (*hastatus*) is very elegant, and another (*Puzosianus*) is very large. At Christian Malford some remarkable specimens of a kind of *Sepia*, having the *cephalic tentacles* and the *ink-bag* still remaining, have been obtained from the Ammonite-bed. The *reptilian* remains are those of *Ichthyosaurus*, *Plesiosaurus*, and a genus allied to the *Teleosaurus* [see Pt. II. Sect. 14, *f*], named "*Steneosaurus*" (from the Greek "*stenos*," narrow) on account of its attenuated form: the Oxford Clay is the earliest Formation in which this reptilian genus has been found, and it is of rare occurrence. It is to be noted that no Corals occur in the Oxford Clay: masses of bituminized *wood*, or poor *jet*, are not unfrequent.

23. The *Coral Rag* has been so called from its consisting in some of its beds in Wiltshire and Oxfordshire of *Corals*, in almost continuous reefs, in the same position as when

living, and of forms which more or less resemble the existing reef-building Corals of the Pacific Ocean: it is sometimes oolitic in structure, occasionally pisolitic, often a shelly rag, and even a marly limestone.

The *Calcareous Grit*, with which the Coral Rag is so intercalated that the two represent one Formation only, occurs as a sand, as a sand including calcareous masses, and as a sandy limestone.

The Formation has a considerable thickness in the South-West of England, in Wiltshire, Berkshire, and Oxfordshire, and again in Yorkshire, near Scarborough; but, with the exception of a small patch near Huntingdon, it has been denuded away from the wide intervening area.

Besides the characteristic *Corals*, many and varied *mollusca*, *Ammonites* of several species (some large), numerous *echinodermata*, and a beautiful *Star-fish*, *Astropecten rectus*, enrich these beds.

24. The *Solenhofen* or *Lithographic Limestone* of Bavaria probably interposes in time between the Coral Rag and the bed which overlies it in this country. This stone is exceedingly fine in texture: hence its use for the purpose of lithographic printing. Its mineral character and the conditions under which it was deposited were such as to result in the most perfect preservation of its embedded organisms, sometimes even of portions of their most delicate structure. Sir Chas. Lyell says—"Although the number of *testacea* (shells) is small, and *plants* few, and these all marine, Count Münster had determined, in 1833, no less than 237 species; among them, seven species of *Pterodactyls* [see Pt. II. Sect. 14, *f*], six *saurians*, three *Tortoises*, sixty species of *fish*, forty-six of

crustacea, and twenty-six of *insects*. These insects, among which is a *Libellula* or Dragon-fly, must have been blown out to sea, probably from the same land to which the *Pterodactyls* and other contemporaneous air-breathers resorted."*

In this bed was discovered in 1862 the almost entire skeleton of a *bird*, so preserved that even the feathers of the wings and tail are perfectly shown. This is the only instance of a fossil bird having been found in beds older than the Cretaceous System; but it is more remarkable for the points of affinity with reptilian forms which it exhibits in several particulars of its osseous structure: for instance, while in living birds the tail feathers are attached to the few terminal vertebræ united or *anchylosed* together, the tail of this fossil bird consists of no less than 20 articulated elongated vertebræ, "each of which supports a pair of quill feathers." Several species of *Pterodactylus* have such a tail, composed of similar elongated vertebræ, to which is attached, not feathers, but the posterior portion of the flying membrane. Such a *Pterodactyle* is found in the same bed as this fossil bird, of a species called *longicaudus* (Latin, "long-tailed"). The bird thus found in a fossil condition was about the size of the Rook: it is in the British Museum, and has been named by Professor Owen "*Archæopteryx macrura*"—from the Greek words "*archaios*," ancient, "*pteryx*," a wing, "*makros*," long, and "*oura*," a tail.

c. The Upper Division comprises the *Kimmeridge Clay*, and the *Portland Oolite* and *Sands*.†

* *Student's Elements*, p. 323.

† See forward, "*Wealden Series*," general remarks, p. 59.

25. The *Kimmeridge Clay* is so called from a village on the Dorsetshire coast, in the cliffs of which it is exposed to a thickness of 600 feet: it gradually thins through Wiltshire, Oxfordshire, and Buckinghamshire, apparently dies out in Huntingdonshire and Cambridgeshire, re-appears in Lincolnshire, and has a considerable thickness in Yorkshire. It occurs also in Sussex, in which county it has been pierced by boring through a vertical thickness of nearly 700 feet.

When the Kimmeridge Clay is preceded by the Coral Rag in the same section, it is based by a series of *passage-beds* * of no great thickness, into which Coral Rag fossils pass up: these beds are typically developed at Weymouth, where they are about 20 feet thick.†

The fauna includes nearly 100 species of *mollusca* and *cephalopoda*, among them a large form of *Oyster*, *O. deltoidea*, and a small one, *Exogyra virgula*, (both very abundant), a large form of *Trigonia* (*clavellata*) and another *T. Juddiana*, *Ammonites biplex*, *A. triplicatus*, *A. mutabilis*, and a curious bivalve shell-like form (called *Trigonellites*, from the Greek "*trigonon*," a triangle, and "*lithos*," a stone, on account of its triangular form), which has been considered to be either the gizzard or the bivalve operculum of a *cephalopod*. Remains of the *Steneosaurus* [Pt. II. Sec. 22], *Ichthyosaurus*, *Plesiosaurus*, *Teleosaurus*, and other *reptiles*, are not rare; but the most remarkable are those of an immense *saurian* called *Pliosaurus* (from the Greek "*pleion*," larger—the larger saurian), which seems to have had affinity, more or less, with all these forms: an idea of the size of "this old

* See *ante*, Pt. II. Sec. 13, *a*.

† The Rev. J. F. Blake, F.G.S., *On the Kimmeridge Clay of England*, Geol. Soc. Jan. 13, 1875.

tyrant of the Oolitic seas"* can be gathered from the facts that one of its crocodilian-like teeth measures a foot in length and three inches in diameter, and that a lower jaw is seven feet long. A small *Ornithosaurian* (Gk. "*ornithos*," of a bird—a bird-like saurian), and a peculiar *Turtle*, have also been found in this Formation.

This Clay is frequently very bituminous, sometimes containing *lignite*, which has been called "Kimmeridge Coal," and used as fuel. This sometimes assumes the character of a poor *jet*, and as such was worked for ornamental purposes by the Romans, and perhaps by an earlier people: some round objects in this material have been miscalled "*coal money*." Some of these bituminous beds are doubtless derived from vegetable matter; but Sir Chas. Lyell suggests that, as the fauna is entirely marine, some of the bitumen may be of animal origin.

26. The *Portland Oolite* and *Sands* derive their name from the Isle of Portland off the coast of Dorsetshire. The Limestone beds form the upper and the Sands the lower portion of this Formation. The former is one of the well-known building-stones of this country: St. Paul's and many other public edifices in London having been built of it. The Formation occurs chiefly in the Southern counties; but the Sands are sometimes found capping the Oolitic hills as far to the North-East as Oxfordshire; at Ely, higher beds immediately overlie the Kimmeridge Clay, the Portland beds being absent; but the Formation is slightly represented near the Vale of Pickering in Yorkshire.

The Portland beds have yielded about 50 species of

* Owen.

mollusca, and the largest known *Ammonite*, "*giganteus*"; specimens of which have been found nearly five feet in diameter. In the Sands, is found a beautiful *Coral* (*Isastræa oblonga*), generally converted into *chert*—a mixed silicious often flint-like material, frequent in limestone.

The Formations of the Oolitic System, like those of the Lias, traverse this country, from Dorsetshire to nearly the North of Yorkshire, in a belt only broken for a short space in the latter county by being overlaid by beds of the Cretaceous System. They consist alternately of beds of hard rock (mostly limestone) and beds of clay or sand; and this peculiar arrangement has had a marked influence in determining the surface contour of the wide belt of country constituting the out-crops of the Oolitic and Liassic Systems. The harder groups stand out as escarpments * facing the West and the North-West; and these alternate with broad valleys formed by the Kimmeridge, the Oxford, and the Lias Clays.

As to the origin of the Limestone Formations of the Oolitic System, Dr. Wright has expressed his conviction that these have been derived directly or indirectly from *Coral* reefs—that even the limestone beds in which Corals themselves are not found have been formed by the deposit of calcareous pulp or mud, the product of Corals destroyed by the action of the sea.†

Sir Chas. Lyell has suggested,‡ as a solution of the question as to the causes of the alternation of argillaceous

* See *ante*, Pt. I. Sec. 21, *d*. An *escarpment*, in a larger sense, is the inclined surface of the out-crop of any great Formation, such as that of the Oolite, Chalk, etc.

† Meeting of *Cotteswold Naturalists' Field Club*, June 25, 1874.

‡ *Student's Elements*, p. 352.

(clayey) and calcareous (limey) deposits during the periods of the Liassic and Oolitic Systems—that, at the commencement of the former, an argillaceous sediment, brought by oceanic currents, was being thrown down upon the bottoms of Liassic seas, unfitting them generally for the existence of *Zoophytes*; that, when from physical causes the muddy deposit ceased and the water became clear, the growth of stony *Zoophytes* set in, and calcareous sand formed from comminuted shells and corals,* and in some cases silicious sand, replaced the clay; that clay again was deposited, to be superseded as before; and that this process was repeated as often as the alternations referred to had occurred. Such alternations must have been varied, however, by not a few changes from marine into estuarine, and even into fresh-water and dry-land, conditions, and the reverse.

27. The WEALDEN SERIES comprises the *Purbeck Beds* † and the *Wealden Beds*.

28. The *Purbeck Beds* are so called from the locality in Dorsetshire in which they are best exposed. They have an aggregate thickness of about 160 feet; are very varied in character, consisting of more or less calcareous slates, marls, and other rocks; and comprise no less than twelve distinct beds, chiefly fresh-water, but including brackish and marine deposits, and at least two land-surface beds. These have been divided into the Upper, Middle, and Lower Purbecks, each containing a distinct group of organic remains.

a. Of the Lower Purbeck, the lowest bed is a fresh-water limestone, which rests immediately upon the Portland Oolite

* See Dr. Wright, *ante*. † See forward, p. 59.

last described. Above it, separated by an interval of six feet, are two "Dirt-beds," so called, consisting of vegetable soil, containing *in situ* the stools and roots of *Cycadeæ, Zamiæ, Coniferæ*, etc., many of the stems of which, partially silicified, lie prostrate in the same soil. Over these are brackish-water deposits; and these are surmounted by fresh-water marls.

b. At the base of the Middle Purbeck, is a thin bed of greenish shales, containing marine shells and plant impressions: over this, is a thin stratum of marl only two or three inches thick, which has yielded, from a very small area, (besides numerous *insects* and air-breathing *mollusca*), the jaws and other remains of no less than 10 genera and 25 species of insectivorous, predaceous, and herbivorous *Marsupial mammalia*, a number exceeding that of all others found in Secondary Formations: these range from the size of a mole to that of a small rabbit; and one is allied to the living herbivorous Kangaroo-rat of Australia. Over this bed, are fresh-water beds, including silicious bands filled with organic forms beautifully preserved, among them the seed of *Chara*, a genus of *water-plants* which still exists. A marine bed containing an *Echinus* and shells of *mollusca* of marine genera succeeds; which passes up into limestones and shales, partly of brackish and partly of fresh-water origin, containing characteristic *mollusca* and *fishes* and a *crocodilian reptile* called "*Macrorhynchus*"—Gk. "*makros*," long, and "*rhynchos*," a beak. Over this, is again a purely marine bed, then a brackish bed, and this is overlaid by a thick fresh-water bed containing shells of *mollusca* and remains of *fish* and *Turtles*. The fossils of the marine beds are of Oolitic genera.

c. The Upper Purbeck is wholly fresh-water, and abounds with shells of *mollusca* and remains of *fish*, all of different species to those of previous beds. It is from this division that the well-known "Purbeck Marble," so widely and so anciently used in the cathedrals and churches of this country, has been obtained: this marble is a close dark-coloured limestone, which bears a good polish, and is rendered very ornamental by its numerous shells seen in section.

In all these divisions occur bands containing a very minute (almost microscopic) *bivalve crustacean*, called *Cypris*; each division having its own particular species, which does not occur in the other divisions.

This remarkable sequence (of fresh-water, dry land, brackish water, fresh-water, sea, fresh-water, dry land, sea, etc., in re-iteration), does not so much imply a rapidity of changes in physical conditions as a great lapse of time which those changes must necessarily have involved; and this is further indicated by the several complete changes in the groups of organic forms which, by slow natural processes, were effected during the deposition of these beds.

29. The *Wealden Beds* consist of three divisions—the lower the *Hastings Sands*, the middle the *Weald Clay*, and the upper the *Punfield Beds*.

a. The *Hastings Sands* consist of sand, sandstone, grit, clay, and shale; *clay*, in spite of the name "*Sands*," being the predominant material. The Formation occurs in Kent, Surrey, Sussex, and Dorsetshire: in the latter county, it is seen to immediately overlie the Purbeck Beds, and exhibits there some lower bands containing shells of brackish-water and marine genera. It has an aggregate thickness probably

exceeding 1,000 feet: in the upper portion in Surrey, it contains thick beds of a soft sandstone, which, in the neighbourhood of Tunbridge Wells, in the form of inland cliffs, adds much to the picturesque scenery of the district.

The Hastings Sands abound with the remains of *reptiles*, including—the *Iguanodon* (so called from the teeth being like those of the largest living lizard, the Iguana, four to five feet long) was probably, although herbivorous, the next largest reptile to the *Ceteosaurus* [see Pt. II. Sec. 19, *b'*], its length having exceeded 40 feet; the *Hylæosaurus* (Greek, "*hylaios*," wood-frequenting), a land-lizard, which had an enormous dorsal crest of spines, and was 25 feet in length; the *Megalosaurus* (30 feet in length), the *Plesiosaurus*, and the *Pterodactylus* [see Pt. II. Secs. 14, *f*, 17, *e* 1]: it also contains two species of *Turtles*, several of *fish*, a fresh-water *bivalve*, *Unio*, and some *Ferns*.

Certain beds at Potton in Bedfordshire, which contain the remains of *Iguanodon* and other Wealden forms, may be an extension Northwards of the Hastings Sands.

b. The *Weald Clay* is for the most part of fresh-water origin, "but in its highest portion contains beds of *Oysters* and other marine shells which indicate fluvio-marine conditions." * It attains a great thickness, exceeding 800 feet. Its most remarkable fossil remains are those of the *Iguanodon* (described above), of which between 70 and 80 distinct individuals have been identified, "varying in age and magnitude from the reptile just burst from the egg, to one the femur of which measures 24 inches in circumference." † Bands of limestone filled with the shells of a fresh-water *gasteropod* (*Paludina*), and which when polished is called

* Lyell's *Student's Elements*, p. 298. † *Ibid.* p. 300.

"Sussex Marble," occur in this bed; as do numerous *Cyprides*, of distinct species to those found in the Purbeck Beds. The Weald Clay occurs in nearly the same districts as the Hastings Sands, and also in the Isle of Wight.

c. The *Punfield Beds.* This Formation was first defined, and has been described, by Mr. Judd.* It occurs in greatest thickness at Punfield in the Isle of Purbeck, and has been recognized in Sussex, the Isle of Wight, and elsewhere. It consists at Punfield of variable beds of clays and sands, the latter sometimes taking the form of ironstones, very like the ironstones of Northamptonshire: these beds are almost entirely of brackish-water origin; but they have a thin marine band at the base (21 inches thick), containing distinctive fossils, of forms which may be considered as intermediate between those of the latest Oolitic beds and those of the oldest Cretaceous beds. It is remarkable that a coal-bearing Formation in Eastern Spain contains the same kinds of fossils as this marine bed. The Punfield Beds have a total thickness of 230 feet.

At Swanage Bay, where is the finest development of the combined Wealden Series, occur:—Punfield Beds, 160 feet; Weald Clay and Hastings Sand, 2,000 feet; Purbeck Beds, 406 feet; total, 2,566 feet. If the increased thickness of the Punfield Beds at Punfield be added, the total thickness of what Mr. Judd calls the "*Wealden-Purbeck*" Series will be 2,636 feet.

The area of the *Wealden Series* extends West and East about 330 miles, from the Isle of Portland to near Boulogne, and North-West and South-East, from Surrey to Vassy in

* *Journal of Geological Society*, 1871, pp. 207–227.

France, about 200 miles; or, if we extend the area to Potton, about 270 miles. Some Geologists would greatly enlarge this area on the Continent.

Geologists generally, because some of the marine bands contain fossils of Oolitic genera, have classed the Purbeck Beds with the Upper Division of the Oolitic System; and, because the lower beds of the Cretaceous System overlie conformably the upper beds of the Wealden Series, are of the same mineral composition, and contain a few mollusca and fish of Wealden genera and the remains of an Iguanodon, they have classed the Wealden Beds with the Cretaceous System.* Sir Chas. Lyell, also, has tabulated the Upper Portion of the Wealden Beds as the "Fresh-water" equivalents of the "Marine" lowest beds (*Neocomian*) of the Cretaceous System.†

Professor Ramsay, however, having come to the conclusion that the Purbeck Beds and the Wealden Beds are the lagoon and delta beds of one immense river, which, flowing through a continent lying to the North and West probably as large as Asia, may have rivalled in size the Ganges or Mississippi,‡ has classed them together as a "Series" intermediate between the Oolitic and Cretaceous Systems. The great aggregate thickness of the Wealden Series (2,600 feet), and its palæontological changes and physical variations, indicate an immense lapse of time; and it is not improbable that, during the deposition of the Lower and Middle Purbecks, the decadence and close of the Oolitic period may have occurred, and that the deposition of the Wealden Beds

* See Folded Table, p. 17. † *Student's Elements*, p. 292.
‡ *Physical Geology*, 3d Edit., p. 85.

may have witnessed the coming-in of the period of the Cretaceous System. The Wealden Series would thus represent in time the *passage** of the one period into the other, and would rightly occupy the intermediate position of Professor Ramsay's classification.

A consideration of the character of the successive beds of the Wealden Series will enable us to form a theoretical idea of the successive physical changes which occurred over the area associated with those beds during the immense period of their formation—that is, during the period which elapsed between the commencement and the ending, as to that area, of the mighty river spoken of by Professor Ramsay.

Towards the close of the period of the Oolitic System, an elevation of that area commenced, and gradually but intermittently proceeded; and a fitful series of changes, from marine to lagoon or estuarine, and thence to fresh-water conditions, correspondingly took place. This elevation was accompanied by the flow, over Oolitic beds and between Oolitic shores, of that great river, and continued (being greatest probably to the North of the area, and lessening towards its Southern regions), until the channel of the river was excavated to the great depth indicated by the thickness of the subsequent fresh-water deposits. At length, elevation and excavation ceased, subsidence commenced, and with it the deposition of sediment in the river's bed: these processes went on in combination until fresh-water deposits had accumulated to the immense thickness already stated of nearly 2,000 feet. But a time came when the river channel had shallowed by its own deposits, and when the high lands

* See *ante*, Pt. II. Sect. 13, *a*.

of its shores had sunk to nearly the sea-level (concurrent denudation having contributed to this result): then estuarine conditions again set in, and estuarine sediments were thrown down over the older fresh-water deposits. Ultimately, the whole area became submerged, and the deposition of the lowest beds of the Cretaceous System commenced; only, however, on what had been the dry-land surfaces of the previous time: for, subject to an occasional marine intrusion, the grand old river for ages held its own, maintained its separate identity far out to sea (as does the river Amazon at the present time), and continued to throw down its sediment within the area of its own stream; while simultaneously the ocean on either hand deposited its material. And thus perhaps it is that we find the brackish-water deposits of Punfield and of the Upper Weald side by side, as it were, and contemporaneous with, the marine deposits of Cretaceous beds.

The fact that incalculable ages must have passed during such changes, is in strict agreement with that of the amazing lapse of time which, for other physical and for palæontological reasons, we know must necessarily have intervened between the close of the Oolitic and the middle of the Lower Cretaceous period.

30. The CRETACEOUS System.

The Cretaceous System is divided into the *Lower* and the *Upper*.*

* In the Folded Table (page 23), I have divided the Cretaceous System into the Lower, *Middle*, and Upper; but Geologists generally class the Formations of the latter two together, and divide the System into Upper and Lower only. In the text, I have adopted this classification.

31. For the *Lower Division* (formerly called the "*Lower Greensand*"), the Continental term of the "*Neocomian*" has generally been adopted. Several of the lower beds of this Division (as stated in the last Section) were doubtless contemporaneous with the later beds of the Wealden Series.

The *Neocomian* group comprises several distinct series of beds, which have been classed as the Lower, Middle, and Upper Neocomian.

At Speeton, in Yorkshire, in a series of clays, having a total thickness of 500 feet, are exhibited the best examples of the beds of the Lower and Middle Divisions of the Neocomian group. These have been fully described by Mr. Judd.*

a. The Lower Neocomian at Speeton has a thickness of 200 feet, and has been re-divided by Mr. Judd into three zones, each marked by its distinctive *Ammonite.*

b. The Middle Neocomian at Speeton is a clay 150 feet thick: it has an equivalent in certain beds of limestone, clay, and ferruginous sands, (of a total thickness of about 70 feet), which occur at Tealby in the Lincolnshire Wolds. Three remarkable fossils characterize this Middle Division—a *bivalve* shell, *Pecten cinctus,* which is nearly 12 inches in diameter; a *cephalopod,* allied to an Ammonite, but having the whorls separated like the open coils of a flat spiral spring, and which has received the generic name of "*Crioceras*" (from the Gk. "*crios,*" a ram, and "*ceras,*" a horn—like a ram's horn); and a very ornamental clawless crustacean (a little larger than a shrimp), *Meyeria ornata.*

c. The upper beds at Speeton, to a thickness of 150 feet, belong to the Upper Neocomian. They are crowded with

* *Journal of Geological Society,* 1868, p. 218.

fossils: as many as 87 species of *mollusca*, numerous *Ammonites* (one three feet in diameter), and fine skeletons of the *reptiles Pliosaurus* and *Teleosaurus*, have been collected from these beds. The presence of a peculiarly-formed bivalve, *Perna Mulleti*, serves to correlate these beds with the lower beds of the series next to be described.

c 1. At Atherfield Point, on the South coast of the Isle of Wight, and stretching along from Shanklin further West than the Black Gang Chine, are a series of ferruginous and other sands, clays, and indurated sands and clays, having a thickness of nearly 900 feet. The lowest beds contain the *Perna Mulleti* mentioned above; and this and some other fossils serve to identify those beds as equivalent to the upper beds at Speeton, and thus to continue upwards that series, although the two localities are separated by a distance of 250 miles.

Other notable fossils from the Atherfield beds are—a *bivalve* having very peculiar curled shells, which has been named "*Diceras*" (two-horned"), and some clawed *crustaceans* like attenuated Lobsters.

These beds contain also fragments and water-worn fossils from Oolitic rocks; which have doubtless been derived from the *detritus* of the denudation of the Oolitic land and shores of the great Wealden river.

c 2. At Folkestone, Hythe, and Maidstone, in Kent, and at localities in Wiltshire, Surrey, and Sussex, occur sands, varying in colour, which attain a total thickness exceeding 500 feet. These are also included in, and are the highest beds of, the Upper Division of the Neocomian group. In Kent, these beds are sometimes intercalated with bands of *limestone*, which is quarried as "Kentish Rag."

c 3. The more prominent fossils of these strata are—a *Nautilus* (*plicatus*), and another *cephalopod*, allied to the Ammonite, but still more nearly allied to the *Crioceras* of the Middle Speeton Clay: like it, the whorls are open, but the outer one is very much enlarged, extends straight outwards as if uncurled, and is curved back at the end towards the mouth: it has been named "*Ancyloceras*" (from the Greek "*agkylos*," curved), and "*gigas*," on account of its great size.

The generic forms *Diceras*, *Crioceras*, and *Ancyloceras*, first appear in the Neocomian group: in which also have been found 21 species of *Ammonites*, only three of which occur in later beds. The total thickness of the whole group is about 1,750 feet. On the Continent this thickness is greatly exceeded.*

32. The *Upper Division* of the Cretaceous System comprises in ascending order—the *Gault*, the *Upper Greensand*, the *Chloritic Marl*, and the three *Chalks*. There is a very complete break between the Lower and Upper Cretaceous Divisions—marked, not only palæontologically by the fact mentioned in the last paragraph, but stratigraphically, by the eroded and unconformable surface of the uppermost Neocomian bed.† A considerable interval of time must have occurred between the deposition of the last bed and that of the earliest Gault bed.

a. The *Gault* (a provincial name) attains a thickness of about 280 feet:‡ it consists generally of a dark blue marly clay, varied by the presence of patches and bands of green sand. It occurs in very numerous localities, cropping out

* D'Orbigny. † See *ante*, Pt. I. Sec. 28, *g*.
‡ Professor Hughes, *Geological Society*, Feb. 10, 1869.

upon almost every escarpment of the Chalk. The well-known "Red Chalk," which gives to the cliff-face at Hunstanton, Norfolk, so vivid an aspect, and which occurs also in Lincolnshire and near Filey in Yorkshire, is probably of this Formation.

Of the organic remains yielded by these beds, 21 species of *Ammonites* are known, eight of which are distinctive, and ten common to higher beds; also two other genera of *cephalopods*, allied to Ammonites—*Hamites* (Latin, "*hamus*," a hook, hook-shaped), and *Scaphites* (Latin, "*scapho*," a skiff, its form partaking somewhat of that of a boat, or rather of a canoe). The Gault fossils are remarkable for the beautiful metallic-like lustre with which they are often invested (a peculiarity sometimes also exhibited by Oxford Clay fossils): this lustre is due occasionally to the presence of metal, but more frequently to the peculiar laminated texture of the pearly shell, which decomposes the rays of light, and covers the fossils with brilliant ever-changing colours, such as those exhibited in the prismatic spectrum or in the rainbow, which are produced by similar refractive causes.

The Gault Clay is worked for bricks; which, after a particular process of burning, are of a pale yellow colour.

b. The *Upper Greensand* Formation interposes between the Gault and the Chalk in all escarpments of the last in the Southern and in some in the Midland Counties. It has a thickness exceeding 150 feet in the Isle of Wight, lessens towards the North, is still important in Buckinghamshire, but thins away in Bedfordshire: it may be present at Hunstanton in a thin band overlying the Red Chalk, distinguishable by an abundance of a ramifying *sponge* (*Spongia paradoxica*), but it does not occur in Yorkshire. West-

wardly, it increases in importance: it has a thickness of 30 feet in Dorsetshire, and appears as an important deposit at Blackdown in Devonshire. The Blackdown beds are low down in the Formation, and repose immediately upon Liassic and Triassic beds; so that the Upper Greensand Formation originally extended over and "overlapped" * all the Neocomian, Oolitic, and Liassic beds, which have either thinned out, or (from the effects of inclination and denudation)† successively cropped out, in that direction.

Many of the fossils of this Formation are allied to those of the overlying Chalk. Of 156 *mollusca* found in the Blackdown beds, 50 species are common to the Neocomian, 16 to the Gault, 20 to the overlying Chloritic Marl, and 60 are peculiar to the Upper Greensand itself. Among the distinctive fossils is a peculiar sponge growing upon a stem with root-like processes, called *Siphonia* (from the Greek "*siphon*," a tube, in allusion to its being composed of a series of tubes), and *pyriformis* (from the Latin "*pyrus*," a pear), pear-shaped.

b'. The question as to the Formation to which the so-called "*Coprolite Beds*" of Cambridgeshire and Bedfordshire are to be assigned, is a disputed point with some Geologists: a preponderance of opinion seems to favour the view that these beds are contained in an attenuated extension of the Upper Greensand. The phosphatic nodules which first gave the name to these beds (and the abundance of which, they being a rich manure, renders the beds so valuable) are with-

* When a Formation extends horizontally beyond underlying Formations so as to rest ultimately upon a still older Formation, it is said to "*overlap*" those Formations.

† Pt. I. Sec. 21, *g*.

out doubt derived from animal decomposition: many of them have been sponges, which gathered phosphatic matter, became consolidated, and were afterwards water-worn; others have had for *nuclei* Ammonites, vertebræ, teeth, etc.: of these, some have and some have not been rolled, as teeth unbroken and unworn sometimes project from the surface; and others may really be "*coprolites*," the *excreta* of fishes and saurians.

Many of the fossils of the "Coprolite Beds" have been "*derived*" * from the denudation of the underlying Gault: others represent life-forms of the age of the deposit. Reptilian remains are very abundant, including "more than ten species of *Pterodactylus*, five or six of *Ichthyosaurus*, one of *Pliosaurus*, one of *Dinosaurus*, eight of *Chelonian*, besides other forms." † The remains of a *bird* rather larger than a pigeon, probably of the Gull tribe, have also been found. Excepting the *Archæopteryx* of the Solenhofen Limestone ‡ and the *Ichthyornis* and *Apatornis* of the Cretaceous beds of the United States (all having reptilian affinities), § and the foot-prints in the American Trias, || this is the only instance of bird remains in Formations of the Mesozoic Life Period.

In the so-called Upper Greensand of Cambridgeshire, the bones of an immense species of *Pterodactylus* have been

* "*Derived*" fossils are fossils which, having been originally embedded in any Formation, have been washed out and re-deposited in more recent beds. They are generally mixed with the fossils proper of the beds in which they are found, and much care is required to recognize them as being "derived." Errors have occurred as to the identity of Formations, and as to the vertical range of genera and species, from the lack of such recognition.

† Sir Chas. Lyell's *Student's Elements*, p. 283.

‡ Pt. II. Sec. 24. § See forward, p. 73. || Pt. II. Sec. 12, *e*.

found, which, according to Professor Owen, "had a probable expanse of wing of from 18 to 20 feet." *

c. Overlying the Greensand Formation and underlying the Lower Chalk, in the Isle of Wight, at Chardstock in Dorsetshire, and other localities, is a remarkable chalky marl bed, "full of green specks of *silicate of iron*, and called in consequence the *Chloritic Marl.*" † Its organic contents, which are very abundant, show that, as stratigraphically it divides the Upper Greensand and the Chalk, palæontologically it unites them; for, in comprising fossils common to each Formation, it represents the *passage* of the former into the latter: while it contains some forms which are peculiar to itself and mark it as being distinct from both. The *cephalopods* include a peculiar genus called *Turrilites* (Greek "*tursis*," Latin "*turris*," a tower), probably first occurring in this Formation. This has a chambered shell, the numerous whorls of which have a very small radius; and these, instead of being flat like those of the Ammonites, rise in an elevated spire like that of some gasteropods. The mouth opening is to the left, the reverse direction of that of gasteropods generally.

In some beds in Surrey, lime is intermixed with sand, forming a stone locally called "malm-rock" and "firestone." In the Isle of Wight, bands of limestone in this Formation contain nodules of chart.

33. The *Chalk Series* is divided into—the Lower or *Chalk Marl*, the Middle or *Chalk without Flints*, and the Upper or *Chalk with Flints*.

* *Palæontology*, p. 274.

† The Rev. T. Wiltshire, in Dr. Wright's Monograph upon *Cretaceous Echinodermata*, *Palæontographical Society*, 1864.

The *passage* upwards, from the Gault to the Upper Greensand, and from the latter, through the Chloritic Marl, to the Chalk, has been shown to be continuous.

a. Probably the oldest Formation to be included under the head of "*Chalk*" is the *Hippurite Limestone* of the South of France, which occurs also in Spain, Italy, Greece, and other countries bordering the Mediterranean. The *Hippurites* are a group of *bivalves* which are very unlike bivalves generally, and have no analogue in any known existing life form. The name is derived from the Greek "*hippos*," a horse; the section of the larger valve being in plan like that of a horse's hoof. The Hippurite Limestone, in its successive beds, may have been synchronous with the highest beds of the Upper Greensand, with the Chloritic Marl, and with the lowest beds of the Chalk in this country, as unique examples of varieties of *Hippurites* have been found in the first and in the last of these Formations.

b. The *Chalk Marl* is the lowest member of the British Chalk series, and rests conformably upon and blends with the Chloritic Marl described in the last Section. It is an argillaceous sometimes grey soft limestone, partaking much of the mineral character of the true Chalk, into which it gradually passes up. It occurs chiefly in the South of England, and has a thickness exceeding 200 feet. Of 32 species of *Ammonites* which its beds have yielded, 7 are peculiar to it, 11 pass up into the Chalk, and 14 have been found in older beds. Among other of its *cephalopods* are *Belemnites*, *Scaphites*, and *Turrilites*. [See *ante*, Pt. II. Secs. 14, *f*, and 32, *a* and *c*.]

c. The *Chalk without Flints* is several hundred feet in thickness, is not of so pure a white as the Upper Chalk,

and is much indurated in parts, probably from a minute crystallization of *carbonate of lime*, the result of aqueous percolation.

Its fossils are not so abundant as those of the Upper Chalk, but partake of the same general character. Of 25 species of *Ammonites*, about half are peculiar to it:* a form of *cephalopod* not found in earlier beds occurs in this Formation; it has a long straight tapering slender chambered shell, and has been called "*Baculites*," from the Latin "*baculus*," a staff. The bones of an immense *Pterodactylus*, the spread of whose wings measured from tip to tip 16 feet 6 inches (second only in size to the Upper Greensand example referred to in the last Section) have been found in beds of this Chalk in Kent.†

Among the remains of *reptiles* in this Chalk, the most remarkable are those of a genus allying the *Lacertia* (lizards) with the *Ophidia* (serpents). These were found many years ago in the Lower Chalk of Sussex, and have been figured and described in *Dixon's Geology of Sussex*.‡ The animal is there called *Dolichosaurus longicallis*—from the Greek "*dolichos*," long, the long lizard, and the Latin "*longe*," long, and "*callum*," neck, indicating its serpent-like character. Professor Owen has described it in his Monograph on the *Reptilia of the Chalk*,§ and states that it was more nearly allied to the lizard than to the serpent. Professor C. G. Seeley also described it at the Meeting of the British Association in 1866; and, considering that it was

* Lyell's *Student's Elements*, p. 281.

† *Ibid.*, and Owen's Monograph on *Cretaceous Reptilia*, *Palæontological Society*, pt. i., pp. 88–97.

‡ Tabs. xxxviii. and xxxix., page 388.

§ In the *Palæontographical Society's* publications, p. 22 and Tab. x.

nearer akin to the serpent than to the lizard, he called it the "Lizard-serpent." But whichever extreme it may favour, it is notable as being the earliest serpent-like form that is known.

d. No plane of unconformity separates the Chalk without Flints from the *Chalk with Flints*, but an intermediate bed of about 130 feet of thickness, containing a few flints only, seems to connect the two.* The *Chalk with Flints* is so distinguished from the fact that it is traversed at vertical intervals of from two to four feet by layers of *flint*, sometimes continuous and of a few inches in thickness, but more often occurring in nodular masses.

d'. The origin of Chalk Flint was for many years an unsolved problem. In the structure of many microscopic animal and vegetable organisms of the Chalk *silex* largely occurs, and the minute *spicula* which constitute the framework of sponges are of pure silex: decomposition having released such silex, "by some chemical processes which, though guessed at, are not yet perfectly understood," † it gathered about and frequently filled the interstices of sponges which grew over the sea floor during intervals of favourable conditions, and about and in other organic bodies, which are now commonly found enclosed and often beautifully preserved in flint. The silex in solution required in the first instance for the formation of microscopic organisms referred to may have arisen from the disintegration of felspathic rocks, more than half the bulk of which is formed of silicious earth.‡

* Dr. Wright's Introduction to Monograph on *Cretaceous Echinodermata*, *Palæontological Society*, 1864.

† The Rev. T. G. Bonney's *Manual of Geology*, pp. 74, 109.

‡ Lyell's *Student's Elements*, p. 273.

d''. The organic remains in the Chalk with Flints are for the most part perfectly preserved.

Of *mollusca, gasteropods* are less plentiful than bivalves or *conchifera* (from the Greek "*kogche*," a Mussel or Cockle). The bivalve genus *Inoceramus*, although not peculiar to the Cretaceous period, is the most characteristic: the shell is large, very thick, and has a strong denticulated hinge. One rare species (*I. involutus*) is very peculiar, the lower valve being very large and curved almost like the whorls of a gasteropod,* and the upper valve very small and flat.†

Cephalopoda are not so plentiful as in the lower beds: they consist of *Belemnites, Baculites,* and *Ammonites*: of about eight species of the latter, six are peculiar to the Formation; as is also a remarkable stemless free-swimming *Crinoid*, called "*Marsupites*"—from the Latin "*marsupium*," and meaning "purse-like." *Echinodermata* are very numerous, and some species are very beautiful: one genus, *Ananchytes*,‡ is very abundant, but limited to the Chalk beds. *Star-fishes*, some of elegant form, and *crustacea*, chiefly allied to the Lobster, are not rare.

Of *fish*, the teeth of Sharks and the palatal teeth of shell-crushers are very abundant, as are the remains of other fish, sometimes almost in a perfect state: among the latter, one (*Beryx*) is nearly allied to the Perch.

Of reptiles, Turtles (*Chelonia*), and *Ichthyosaurus, Plesiosaurus, Mososaurus*,§ and *Pterodactylus*, occur.

* A specimen in flint from Glacial Gravel, at Bugbrooke, Northamptonshire, measures six inches across the volution.

† *Inoceramus involutus* is beautifully figured in *Dixon's Geology of Sussex*, Tab. xxviii. fig. 22.

‡ From the Greek "*Ananchitis*," a kind of gem, unrecognized.

§ See forward, under the head of the *Maestricht Beds*, p. 77.

d'''. In Upper Cretaceous beds of Kansas, United States, Professor Marsh, an eminent American palæontologist, discovered, in 1872, remains of a form which, although distinctly a *bird*, exhibited, in a series of socketted teeth in both jaws, apparently unencased in a horny sheath or beak, a marked affinity with *reptilian* forms. It was about the size of a pigeon, and probably carnivorous and aquatic.* Professor Marsh has given it the generic name of *Ichthyornis*; and, another allied form (*Apatornis*) having been discovered, he proposes to establish a new order *Ichthyornithes*, and a new sub-class of birds *Odontornithes* or *Aves dentatæ*.†

The conclusion to which the character of the fauna of the Chalk, reasoning by analogy, would lead us is, that a warm climate prevailed over the Cretaceous area; but the warm ocean must have been traversed by icebergs, for pebbles and boulders of materials of older rocks (some Palæozoic) have been found embedded in its deposits, the presence of which can only be accounted for by the fact that they were ice-borne.

The material of the White Chalk is in the main nearly pure carbonate of lime. It is almost entirely made up of various forms of animal matter; for microscopic examination demonstrates that in many beds 95 per cent. consists of the calcareous cases of *Foraminifera*,‡ fragments of other minute shells, and certain still more minute ova-shaped

* Woodward—*Journal of Geol. Soc.*, 1874, p. 10.

† *American Journal of Science and Art*, vol. v., Feb. 1873.

‡ Called "*Foraminifera*," from the Latin word "*foramen*," a puncture, on account of certain perforations in the shells of these very minute life-forms.

organic objects called *Coccoliths*,* *Coccospheres*, and *Discoliths*,† of which the true nature has not yet been certainly ascertained; but of the silicious, some are *Diatomaceæ* and and others possibly of other vegetable origin.

Some light has been thrown upon the probable process of the Formation of Chalk by the scientific deep-sea dredgings which have been carried on in the Atlantic for some years. The floor of the ocean, often at a depth exceeding two miles, has been found to consist of a white calcareous mud, almost entirely composed of the shells of *Foraminifera* of the genus *Globigerina*, mixed with the silicious shells of other microscopic forms, the silicious skeletons of the as minute somewhat paradoxical vegetable objects *Diatomaceæ*, and the *spicula* of sponges: these are connected by "a mass of living gelatinous matter," to which Professor Huxley has given the name "*Bathybius*,"‡ and which contains also an abundance of *Coccoliths* and *Coccospheres*, similar to those found as fossils in the Chalk: these last occur also at still greater depths (three miles), in a white chalky mud, containing no *Globigerina* nor any other organic remains visible to the naked eye; their presence having been detected upon microscopical examination by Mr. Etheridge.§ More recent deep-sea dredgings have shown that upon "such white mud there sometimes flourish—*mollusca*, *crustacea*, and *echinoderms*, besides abundance of silicious *sponges*; forming on the whole a marine fauna having a striking resemblance in its general character to that of the ancient Chalk." ‖

* Greek "*kokkos*," any small round body.
† From "*diskos*," anything round and flat.
‡ From the Greek "*bathys*," deep.
§ Lyell's *Student's Elements*, p. 271. ‖ *Ibid.*

Because of these facts, some have rushed to the false conclusion that the Chalk period is still represented in the present Atlantic sediment, and that that period has lasted on to, and indeed includes, the present time. The discoveries referred to are exceedingly instructive, being suggestive of the conditions under which our thick Chalk beds (exceeding 1,400 feet)* accumulated in the profound depths of the ocean during the long ages of the Cretaceous period; but, although the occurrence of similar conditions in the Chalk age and in the present has naturally resulted in certain similarities in some very small forms and through a very small proportion of the faunas of the two, yet the differences between the great life-world of the one and the great life-world of the other are so essential as, on this account alone, to divide the Chalk period from the present period as effectively as they are separated by the immense lapse of time which has intervened between them.

The peculiar contours of the Chalk (in the Downs, the rounded surfaces, the coombes and valleys, the bold coast-like head-lands standing out upon and over-looking the wide-spread flats of Upper Greensand and Gault), and the general features of the great Wealden area of Sussex and Kent, are the results of sub-aerial denudation—of frost, and rain, and running water.† The nature of the material of Chalk renders it peculiarly amenable to the dissolving action of water charged with carbonic acid, even when impregnated only with the small amount which rain-water acquires in passing through the atmosphere.‡ By such action, "pipes" or perforations of various depths and diameters (filled with

* Bristowe—Sheet 56 of *Horizontal Sections of Geological Survey*.

† Part I. Sect. 15, *a*. ‡ Pt. I. Sect. 22, *b*.

loose materials from above) have been eaten into the body of the Chalk; and by the same action, the higher Chalk surfaces have been, and are being, wasted and rounded, the *detritus* being carried away by rills and brooks and rivers: the further share of these in the work of abrasion is contributed in the frittering out of valleys and coombes. Sub-aerial denudation is also constantly active in fashioning the physical aspects of the country, in shaping the jutting headlands, and in effecting the slow but constant recession of the varied escarpments.

It once was considered by eminent Geologists that the Chalk escarpments of the Wealden area had been sea-cliffs, which marked the line (and the cessation, in consequence of the elevation of the area,) of old marine denudation—a denudation which had removed the Cretaceous beds, and exposed the Wealden beds throughout their present area, measuring from twenty to forty miles from North to South, and nearly eighty miles from East to West; but Professor Ramsay has shown that this "great amphitheatre" of the Weald has been cleared of the overlying beds (many hundreds of feet in thickness) chiefly by the atmospheric agencies involved in the term "sub-aerial denudation." The whole of the remarkable phenomena connected with the inland denudation of the Chalk are thus traceable to these apparently all-inadequate agencies; the potentiality of which for effecting such great results could only exist in their slow but persistent action through incalculable periods of time.*

* See Ramsay's *Physical Geology of Great Britain*, chap. viii.; Whittaker on Subaerial Denudation, Geol. Mag., 1867; and Foster and Topley on the Denudation of the Weald, Journal of Geological Society, 1865, pp. 443–474.

White Chalk of nearly uniform character has been found to extend from the North of Ireland to the Crimea, a distance in a North-West and South-East line of 1,140 miles, and from Sweden to the South of Bordeaux, a distance in a North-East and South-West line of 840 miles. In Southern Russia, it attains a thickness of 600 feet, retains the same mineral characters as in this country, and includes nearly the same series of fossils.* Throughout a considerable portion of this vast area, the Chalk beds, by internal movements of the Earth, have been thrown into a series of immense *synclinal*† curves or troughs; in three of which, respectively termed the London, the Hampshire, and the Paris "Basins," have been deposited certain Tertiary beds to be hereafter described. The intervening *anticlinals*, to a great extent, have been wasted by denudation.

e 1. Higher than any Chalk beds in this country are beds at *Maestricht* on the banks of the river Meuse in Belgium, which there overlie the ordinary Chalk with Flints. These have a thickness of about 100 feet: the upper (20 feet) abound with *Corals* and *Polyzoa*, the middle (50 feet) are a soft yellow limestone, and the lowest (30 feet) pass down into White Chalk. These beds contain many Chalk *mollusca*, comprising several genera of *cephalopoda*, such as *Belemnites*, *Baculites*, and *Hamites*, which do not occur in any more recent beds; but with these are associated some few genera of *gasteropods*, such as *Voluta*, etc., which, with the exception of these beds, are not found in any Formations earlier than those of the Tertiary Division.

As far back as the year 1766, the remains of "a gigantic

* Lyell's *Student's Elements*, p. 270.

† See *ante*, Pt. I. Sect. 21, *e*.

marine lizard," allied to the *Crocodilia* (but much larger than the largest existing Crocodile), was found in the subterranean quarries of St. Peter's Mount at Maestricht. It was fully described by Cuvier, and afterwards named by Conybeare "*Mosasaurus*," from the Meuse river. This reptile was at least 25 feet long, and the skull nearly four feet long, the jaws being armed with a most formidable array of teeth: this skull was removed by the French Republican army in 1795 to the Garden of Plants at Paris, where it still remains. An excellent cast of this skull may be seen in the British Museum. Teeth of *Mosasaurus*, but on a smaller scale, are found rarely in the Chalk with Flints of this country.

e 2. At *Faxoe*, in the island of Seeland, Denmark, are yellow limestone beds, which are very similar to those at Maestricht, and also rest upon the White Chalk with Flints. One portion is composed of *Corals*, even more conspicuously than is usual in recent Coral reefs. These beds contain 30 species of *gasteropods* (usually rare in the White Chalk), and *bivalves*, *echinoderms*, *zoophytes*, and a *Belemnite*, of species identical with those of the true Chalk: they contain, too, a *Baculite* found in the Maestricht beds, and a *Nautilus*, of a species (*Danicus*) which is found for the first time in this bed but occurs also in the bed next to be described.*

e 3. In the neighbourhood of Paris, and in some other localities in France, is a *Pisolitic Limestone*, "a coarse yellowish limestone," having a thickness of about 100 feet, which occurs in patches only, and rests unconformably upon

* Lyell's *Student's Elements*, p. 269.

the White Chalk. Of its fossils, more than 50 species, "in their aspect," are more Eocene than Cretaceous: it also contains fossils of true Cretaceous character, some forms common to the Maestricht beds, and the *Nautilus Danicus* and other fossils of the Faxoe beds; but no Ammonites, Hamites, Scaphites, Turrilites, Baculites, or Hippurites, so characteristic of the several British and Continental Chalk Formations, have been found in them.

Thus, the Palæontological evidence clearly connects, with some indications of succession, the true Chalk with the Maestricht beds, the Chalk and the Maestricht beds with the Faxoe beds, and the Faxoe beds with the Pisolitic Limestone of France. The same evidence—in the presence of some *Tertiary genera* in the Maestricht beds, and in the presence of many fossils of Tertiary "aspect" and the absence of certain significant *cephalopods* in the Pisolitic Limestone—seems to indicate the position of these several Formations as intervening between the latest Chalk beds of this country and the oldest Formations of the great Tertiary Division which succeeds; and to exhibit a *reaching towards*, but by no means a passage into, those later Formations.

D. Tertiary Strata—Cainozoic Life Period.

It has been stated that the fauna of the most recent Cretaceous age exhibits "a reaching towards" the fauna of the earliest Tertiary age: yet the break between the two, as indicated by the utter change in animal and vegetable life, is so complete as to be without a parallel in the Earth's Geological history. The Belemnite, the Ammonite, and

allied cephalopods having chambered shells (with the exception of the Nautilus), are wholly absent in the Tertiary seas. The great Ichthyosaurus, Plesiosaurus, Mosasaurus, Pterodactylus, and other saurians, which seemed in the Chalk period to be in the very meridian of their development, have disappeared. Not a species (except some perhaps of microscopic forms), whether of mollusc, or cephalopod, or fish, or reptile, or mammal, or plant, has remained—the whole world of life has changed. A vast gulf intervenes, as yet unbridged by science—a lapse of time so great as perhaps to equal that which separates the earliest Tertiary age from our own.* Of the history of this great interval, of its physical phenomena, of its life changes, we know nothing. Whole genera and families of living things may have come into being and passed away, continents may have given place to oceans, and oceans to continents, whole ranges of mountains may have raised their lofty peaks, and again subsided into plains, during this mighty hiatus which human knowledge fails to fill. Geological research, however, may yet, in some region of the Earth, discover Formations and explore strata representing this lost time, and supply the links that are here wanting in the chain and "*continuity*" of the World's life-history.

This chasm aptly separates the "*Secondary*" from the "*Tertiary*" Division of Strata, and the "*Mesozoic*" from the "*Cainozoic*" Life Period.

34. The EOCENE System is divided into the *Lower*, the *Middle*, and the *Upper* Eocene.

* Lyell's *Student's Elements*, p. 264.

35. The *Lower Eocene* consists of—

a. The *Thanet Sands* (so called by Professor Prestwich from their being well exposed in the Isle of Thanet) are the lowest beds of the Eocene group in this country, no Formation intervening between them and the White Chalk. They occur also "in the Northern part of Kent, on the sea-coast between Herne Bay and the Reculvers." * Their greatest thickness is about 90 feet, and they contain some marine *mollusca* which are peculiar to them; such as, *Aporrhais*† *Sowerbyi* and *Scalaria*‡ *Bowerbankii* (*gasteropods*), *Cyprina Morrisii* and *Pholadomya cuneata* (*bivalves*), etc.

a'. Near Beauvais, in the North of France, are marine sands (called the *Sables de Bracheux*) which coincide in age with the Thanet Sands: in them has been found the skull of a quadruped allied to a bear, which has received the name *Arctocyon primævus* (from the Greek "*arktos*," a bear, "*kyon*," a dog, and the Latin "*primævus*," primeval); and this is the oldest Eocene Mammal yet discovered.

b. The *Woolwich and Reading Series* (formerly called the *Plastic Clay*, having been used for pottery purposes) occurs in the places named and at Blackheath in the "London Basin," § in the Isle of Wight and near Bognor in the "Hampshire Basin," § and at Newhaven in Sussex. The shells which have been obtained from these beds indicate a varying succession of fresh-water, estuarine, and marine conditions.

* Lyell's *Student's Elements*, p. 252.

† *Aporrhais*, spout-shell, a name adopted by Aristotle in the fourth century B.C., from the Greek "*aporrheo*," to flow away.

‡ From the Latin "*scalaris*," like a ladder.

§ See *ante*, p. 77.

b'. Two fresh-water or estuarine shells, *Cyrena cuneiformis* and *Melania inquinata*, which have been found in these beds, occur also in the equivalent *Argile Plastique* near Paris; in which also have been found bones of a gigantic bird (*Gastornis Parisiensis*) "as large as an Ostrich, but more robust, and with affinities to wading and aquatic birds." *

c. The *London Clay* consists of brown and bluish gray clay, and attains a thickness of 500 feet. It occurs at Highgate, passes under London, reaches its greatest thickness in the Island of Sheppey at the mouth of the Thames, occurs near Harwich in Suffolk, and near Bognor in Sussex.

c'. The lower portion, to a thickness of some 450 feet, is entirely of marine origin, as shown by the *mollusca*: these number 266 species, of which 160 species are peculiar to the Formation. About 5 per cent. are of existing species; and these are the earliest forms (not microscopic) which identify the past with the existing fauna. The *Nautilus* is commonly found in these beds, but does not occur in later Formations (nor in the existing seas) of the British area.

c''. The upper 50 feet at Sheppey represent estuarine deposits or those of the delta of an important river. They abound with *tree* and other *plant* remains, having affinity with genera now existing in Australia, the Philippine Islands, and Southern India. In these beds, have been found—the teeth and bones of *Crocodiles* and large *Turtles*†; a serpent of Boa-constrictor affinity, 12 feet in length, (*Palæophis*, old-snake, being the earliest true serpent yet

* Owen's *Palæontology*, p. 328.

† "More species of true Turtles have left their remains in the London Clay, at the mouth of the Thames, than are now known to exist in the whole world; and all the Eocene *Chelones* are extinct."—Owen's *Palæontology*, p. 317.

discovered) * ; the remains of *quadrupeds* of genera also now first appearing, including—an *Opossum*, an animal of the porcine tribe (*Chæropotamus*, river-hog) with tusks like ordinary canines,† a large beast (*Hyracotherium*) remotely allied to the Rhinoceros, a kind of *Tapir* (*Lophiodon*, crest-tooth), and a still larger animal of the same family (*Coryphodon*, peak-tooth).

It is to be observed that, of the *mammalia* of these early Tertiary Formations, by far the greater number are nearly allied to the *Tapiridæ*, river-frequenting animals, living chiefly in South America, but also in Sumatra, Malacca, and Borneo.

Besides these fossils, are the bones of a gigantic *bird* of the *Ostrich* tribe (*Dasornis* ‡ *Londinensis*), as large probably as the extinct Madagascar Bird, *Æpyornis maximus* (the greatest tall bird), the eggs of which are from 12 to 14 inches in diameter. An "*Ornitholite*" (bird-stone), however, is the most remarkable of the whole series of organic remains which this Formation has yielded, "on account of the transitional character which it manifests to the *Pterosaurian* § order," of which the *Pterodactylus* is the typical genus: this is the skull, about six inches long, of a true bird, having mandibles furnished with unsocketted "bony tooth-like processes," ten on each side of both upper and lower mandibles. Professor Owen concludes that the living animal "was a warm-blooded feathered biped, with wings, and further that it was web-footed and a fish-eater, and that in the catching of its slippery prey it was assisted by this *Pterosauroid* armature of

* *Vide* Owen's Monograph (Palæontographical Society), "*Reptilia of the London Clay, Ophidia*," pp. 56, 63.

† Only now represented by the *Peccaries* of South America.

‡ From the Greek "*dasys*," a downy bird. § Winged Lizard.

its jaws." Professor Owen has named this *sauroid bird* "*Odontopteryx*"—from the Greek "*odous*," a tooth, and "*pteryx*," a wing.*

d. In France, the *Soissonnais Sands* (according to the opinions of Sir Chas. Lyell and Professor Prestwich, based upon the consideration of about 300 species of *mollusca* which they have yielded, of which only about 33 species are identical with those in the London Clay,) interpose in date between the latter and the oldest beds of the Middle Eocene group in England. The London Clay is not represented in France, or only partially so by these beds.†

36. The *Middle Eocene* consists of—

a. The *Bagshot Sands*, a series of variously coloured marine sands and clays of considerable thickness, which occur South of London, in the locality from which they derive their name, in isolated patches or "outliers" as left by denudation. They are almost unfossiliferous.

b. At *Alum Bay* in the Isle of Wight, and near Bournemouth in Hampshire, are sands which are probably the equivalents of the lower portion of the Bagshot Sands. Some white clay bands in these sands abound with remains of *plants*, sometimes beautifully preserved: as many as 40 species have been identified; and these, in the main, are allied to types occurring in the flora of Australia and subtropical India. Shells of the *Unio* are evidence that these bands are of fresh-water origin.

c. In *Bracklesham Bay*, on the Eastern part of the Hamp-

* See Paper on a "Dentigerous Bird" in *Journal of Geol. Soc.* 1873, p. 511, with plates.—See also the Cretaceous "*Ichthyornis*," *ante*, p. 73.

† Lyell's *Student's Elements*, p. 259.

shire coast, are green clayey sands which have been recognized as equivalent to the upper portion of the Bagshot Sands, and which are rich in marine *mollusca*, the general character of which points to a tropical or sub-tropical climate. Mr. Etheridge has shown that as many as 393 species have been obtained; of which, 240 are peculiar to the Formation, 70 common to the older London Clay, and 100 to the newer overlying beds. Of the bivalves, the large *Cardita planicosta* is common to both Bagshot and Bracklesham; and of the gasteropods, the huge *Cerithium giganteum* occurs also in corresponding French beds, reaching sometimes a length of two feet.

Among other fossils from Bracklesham, are—bones of two species of *serpents* of the genus *Palæophis* * (allied to that from the Sheppey beds, see page 82), one of which, 20 feet in length, Professor Owen has concluded was a sea-serpent; *Crocodiles*, of the genus *Gavialis*; and *fishes*, including four genera of *Sharks*, etc.

d. In the equivalent *Calcaire Grossier* of the Paris Basin, besides *mollusca* to the number of 400 species, nearly identical with those of the English beds, there have been found the remains of *fishes* and *reptiles*, and the bones of the *mammalia*, *Palæotherium* ("old wild beast") and *Lophiodon* ("crest-tooth"), both of which were Tapir-like animals.

e. The *Lower Calcaire Grossier* and the under-lying *Soissonnais Sands* (see *ante*, p. 84) are characterized by an abundance of a small *foraminiferous* shell of the genus *Nummulites* (so called from the Latin "*nummus*," money, its form being round and flat like a piece of money).

* *Vide* Owen's Monograph (Palæontographical Society), "*Reptilia of the London Clay, Ophidia*," pp. 56–63.

Nummulites also sparingly occur in some higher Eocene Formations.

f. The greatest point of interest presented by the *Middle Eocene* group is—that a Formation coeval with these *Nummulitic* beds, and called the "*Nummulitic Limestone,*" is the thickest, the most widely spread, and probably the most significant, of all the grand series of Formations which range between the close of the great Primary Division and the present time. This Formation occurs in the Swiss Alps at a height of 10,000 feet above the sea-level, and has there a thickness of several thousand feet; it also occurs in the Pyrenees, in Algeria, in Morocco, in Egypt (where at the same time it supplied a natural foundation and the stone for building the Pyramids), and in Palestine (where it caps the Chalk Formations of the Mount of Olives); it is traceable through Asia Minor,* across Persia to the mouths of the Indus, in the mountain ranges to the North-West of the Indian peninsula, in Bengal, and in China; and it has been found in Western Thibet, at a height of 16,500 feet above the level of the sea.

It is clear, as Sir Chas. Lyell says,† that the great mountain chains of the Alps, Pyrenees, Carpathians, and Himalayas, "into the composition of whose central and loftiest parts the *Nummulitic* strata enter bodily," could have had no existence until after this period, during which the sea flowed where these chains now rise; for the Nummulites found as fossils in their central and highest rocks "were unquestionably inhabitants of salt-water." The conditions of the ocean

* Many of the ancient Grecian temples were built of it, and it supplied some of the marble for Greek statuary.

† *Student's Elements*, p. 261.

bottoms in which the Nummulitic sedimentary deposits were formed were doubtless analogous to those of the Chalk sea-bottoms, and to those of the bottom of the Atlantic at the present time.* But before the formation of these great mountain ranges, and before the very sediment of which they were composed had been deposited in ocean depths,† the area of this country had been inhabited by "various quadrupeds, by herbivorous pachyderms, by insectivorous bats, and by opossums." ‡

g. At *Monte Bolca*, near Verona, North Italy, are beds of fissile limestone intermingled with a series of submarine volcanic deposits: these contain well-known species of *Nummulites*, and are thus shown to be of Middle Eocene date. They abound with marine fishes beautifully preserved, as many as 133 species having been described by Agassiz.

h. In North America, nearly upon the same Geological horizon, occur beds similar to, and probably the equivalents of, the *Nummulitic Limestone* of the Old World. They contain Eocene fossils, and the remains of numerous individuals of an immense marine mammiferous animal, a carnivorous Whale, which reached a length exceeding 70 feet, and to which Professor Owen has given the name of *Zeuglodon* ("yoke-tooth") on account of its dental peculiarities. §

37. The *Upper Eocene.*

a. In the Isle of Wight, and at some points on the opposite mainland of Hampshire, occur certain Sands overlying a thick Clay, which some Geologists would hesitate in

* See *ante*, pp. 73–75.
† Lyell's *Student's Elements*, p. 249. ‡ *Ibid.* p. 262.
§ *Palæontology*, p. 377.

separating from the Bagshot and Bracklesham beds. At *Barton Cliff*, near Lymington, Hants, the Clay attains a thickness of nearly 300 feet, and abounds in marine shells, for the most part beautifully preserved. Of 321 species of these, not more than 140 are common to the Bracklesham beds; a sufficient palæontological reason for distinguishing the Formations, although there may be no absolute stratigraphical break.

b. The *Headon Series*, deriving its name from Headon Hill, Isle of Wight, occurs also at Whitecliff and Alum Bay in the same Island, and at Hordwell near Lymington. The top and bottom beds are of fresh-water origin, while the intermediate beds are in part estuarine and in part marine, the latter containing many beautiful *Corals*. Among the shells, a minute *land-shell* (*Helix labyrinthica*) is remarkable as occurring in a living state only in America. Seven species of *Turtles*, an *Alligator*, a *Crocodile*, two species of *land Snakes*, and the existing *Bony Pike* of the American rivers, have been found in these beds; which have also yielded numerous extinct *amphibious mammalia*, and a *carnivorous mammal*, remarkable as being probably the oldest yet known among British fossils.

c. The *Osborne* or *St. Helen's Series* (the localities in which it occurs being indicated by its names) is of fresh-water and estuarine origin, and its beds are very variable in character and thickness. Near Ryde, a freestone is obtained from it, which is much used for building purposes: it is called the Nettlestone Grit.

The three Formations last described have equivalents in French beds; but these present no peculiarities requiring particular notice.

d. The *Bembridge Series* occurs near Yarmouth and at other places in the Isle of Wight. It consists of a series of marl, clay, and limestone beds of fresh-water, estuarine, and marine origin, and contains shells in accordance with these several conditions. In them have been found the remains of *Turtles*, and of *mammalia*; the latter comprising no less than six species of *Palæotherium*,* one of *Cheropotamus*, two species of *Anoplotherium* ("unarmed wild beast"), "a lighter and more elegant form"† of Tapiroid than the former, and presenting some rudimentary and foreshadowing characteristics of the *ruminantia*,‡ and one of *Dichobune*, a genus allied to the *Anoplotherium*.

e. The Upper Beds of the Upper Eocene are represented in France by the remarkable *Gypsum Series of Montmartre*, which has acquired a world-wide fame, not only as the source of the manufacture of Plaster of Paris, but as the deposits whence were obtained the rich series of remains of mammalia, birds, reptiles, and fish, in the study, classification, and description of which, the great Cuvier, in the early days of modern Geology, added so much to the world's knowledge and to his own renown.

The mammalia of these beds consist of upwards of 50 species, a great majority of which were of Tapiroid genera, such as *Palæotherium* and *Anoplotherium* (already described) and *Xiphodon*§ *gracile*: the last was about the size of a Chamois, and, as Cuvier inferred from its skeleton, "as light, graceful, and agile as the Gazelle." The remains of a few carnivorous animals have also been found; among

* See *ante*, p. 85. † Owen's *Palæontology*, p. 367.
‡ Animals which chew the cud, such as the Ox, Deer, etc.
§ From the Greek "*xiphos*," a sword—sword-toothed.

which are *Hyænodon* ("Hyæna-tooth"), a *Dog* (*Canis Parisiensis*), and a *Weasel*; those of a *Squirrel*, an *Opossum*, and a *Bat*; besides about 17 species of *birds*, and numerous species of *reptiles* and *fish*: none being referable to existing forms. "The tribe of land quadrupeds most abundant in this Formation is such as now inhabits alluvial plains and marshes, and the banks of rivers and lakes—a class most exposed to suffer by river inundations," * and most likely, therefore, to be entombed in river and lake deposits.

38. The MIOCENE System is divided into the *Lower* and *Upper* Miocene.

39. The *Lower Miocene* is very scantily represented in this country:—

a. The *Hempstead Beds*, in the Isle of Wight, which have a thickness of about 170 feet, and consist of several alternating series of fresh-water and estuarine sands and marls, succeeded above by marine sands and clays. These beds are by some Geologists classed with the Lower Eocene because the fauna agrees with the fauna of that division, and by others with the Lower Miocene because the flora is of that period. They are probably *passage* beds, and represent a period of transition between the two. These beds contain the remains of *mammalia*, in genera akin to, although in species distinct from, those of the Bembridge Beds.

a'. The thick lignite deposits at *Bovey Tracey*, near Exeter, and plant beds alternating with volcanic deposits in the Scotch *Isle of Mull*, comprise all the Formations in this country that are certainly assignable to this period. The flora of these indicates the existence of a sub-tropical climate.

* Lyell's *Student's Manual*, p. 255.

b. Lower Miocene Formations occur in many parts of Europe, of a very variable character, and to a very great thickness. They occur in Switzerland to a thickness of several thousand feet, and to a height of from 5,000 to 7,000 feet above the sea-level. These are for the most part of fresh-water origin, although some are certainly brackish-water deposits, and a still smaller proportion marine.

Many of the *mammalia* of which the remains have been found in these beds are nearly allied in genera to mammalia of the Upper Eocene age; and they comprise in addition—two hornless species of *Rhinoceros*, two small ruminants (*Microtherium*, a "small beast," and *Dorcatherium*, a "deer-beast"), a small rodent (*Titanomys*), the precursor of the Horse (*Hipparion*, "little horse"), and a formidable carnivorous animal as large as a Lion (*Machærodus*, "sabre-tooth"); all of which appear for the first time in these beds. Besides these, there are the teeth of *Sharks* and other *fish*, including those of the immense Shark *Carcharodon*.

b'. The flora of the European Lower Miocene is very abundant, and is particularly remarkable from the significant fact that a considerable number of its genera are very closely allied to existing American forms. Its general character indicates a sub-tropical climate.

b''. In the Croatian Province of Hungary, are beds of this age, which contain, in a hard marlstone, more than 200 species of fossil *plants*, and a very rich *insect* fauna, including 10 species of *White Ants*, some of gigantic size, large *Dragonflies* and *Grasshoppers*, *Beetles*, and *Butterflies*: of the wings of one example of the last, not only is the colour retained, but the pattern also, so as to have enabled Professor

Heer to correlate it with the species *Vanessa Hadena* of India.

b''. In several localities in the Rhine districts of Germany are peculiar *plant* deposits, not so hard frequently as ordinary lignite, but which, because of their usual colour, have been called the *Brown Coal*. These beds frequently contain the remains of *fishes*, *insects*, etc., well preserved.

c. Fossil *plants* of the Lower Miocene age have been obtained from the *Arctic Regions*—from Iceland, Spitzbergen, and Greenland, as far North as the 70th degree of latitude—amounting to 194 species; of which no less than 137 species are from Greenland, one-half being of trees, although there are no trees now growing in Greenland. One-third of the number of species are identical with the species of the Lower Miocene of Central Europe, and all point to the prevalence even in those regions of a warm climate.

d. In the regions of the Upper Missouri in North America, fresh-water beds of the Lower Miocene contain bones of land and fresh-water *Chelonians* and of extinct quadrupeds; many of the same genera as those of the equivalent beds in Europe, but some differing in species. Of the last, are a huge *Tapiroid* (larger than any known earlier species, and called *Titanotherium*), a *ruminant* allied to a form found in Miocene beds in the Siwâlik Hills in India, and a species of the great carnivorous *Machærodus* already mentioned.

40. The *Upper Miocene* is not represented in this country, except that perhaps the "derived"* mammalian remains of the Crag Formations† are relics of an Upper Miocene

* See *ante*, p. 67. † See forward, Section 42.

land which occupied an area including probably that of the present German Ocean.

It is largely developed on the Continent—in France, in Belgium, the Rhine districts, in Switzerland, in the Vienna Basin, in Italy, and in Greece: it is also found in India, and in the United States.

a. The deposits in the Valley of the Loire called the "Faluns" (a French agricultural term), which Sir Chas. Lyell selected as typical Upper Miocene beds, consist of shelly sand and marl, and are lithologically much like the Coralline Crag of Suffolk.* Similar beds occur in Britanny, in the country South of Tours, near Bordeaux, in the country about Toulouse, and in several districts in the South of France; also in Belgium, and in Italy in the range of hills which includes the well-known Superga† near Turin.

These beds consist variously of marine, estuarine, and fresh-water deposits. Of rather more than 300 species of *mollusca* obtained from them, as many as 72 are identical with existing species.

a'. In *mammalia*, a great advance as to the number and character of species, compared with the mammalia of older Formations, is observable. In addition to some previously existing *Tapiroids*, we have the immense animal (first made known by Cuvier as the "*Tapir gigantesque*") the *Dinotherium* ("huge beast"): the length of a skull in the British Museum (*i.e.* between its posterior and anterior extremities)

* See forward, Section 42.

† In Part I. Section 15, *c*, it is inadvertently stated that the mountains of the Superga are formed by the moraines of ancient glaciers on the Southern side of the Alpine chain. The mountains or hills so formed lie between the Superga and the Alps.—*Vide* Sir Chas. Lyell's *Principles of Geology*, 11th edit., vol. i. p. 205.

is 3 feet 8 inches, and from its lower jaw, deflected downwards and backwards, project two immense tusks. The *Hippopotamus* (river-horse), *Rhinoceros*, and a very large and peculiar variety of Elephant (the *Mastodon*, from the Greek "*mastos*," a nipple, "*odous*," a tooth—the teeth, which are very unlike those of subsequent Elephants, being perhaps intermediate between those of Tapiroids and those of Elephants), now first appear; as do several species of *deer*, a kind of *Giraffe* (*Helladotherium*, "Greek beast," having been first found in beds of this age near Athens), and several species of *Apes* and *Monkeys*; and, of marine mammalia, the *Dolphin*, the *Walrus*, and a species of the *Manatidæ* or Sea-cows. Bones and teeth of the great carnivorous feline animal *Machærodus* also occur in these deposits.

b. The Upper Miocene beds of the *Vienna Basin** consist of sands, conglomerates, limestones, and clays. Of their *mollusca*, no less than 500 species of *gasteropods* have been described, of which one-fifth are identical with species living in the Mediterranean, African, and Indian Seas; but the proportion of existing to extinct species of *bivalves* is greater than this.

Of *mammalia* have been found—*Dinotherium*, *Mastodon*, *Rhinoceros*, *Acerotherium* ("hornless Rhinoceros"),† and *Hippotherium* ("horse-beast") or *Hipparion* ("little horse"), a link between the Horse and some forms of the Tapiroids, and the foreshadowing type (perhaps the progenitor) of the existing Horse.

c. These remains are all found in corresponding beds at *Eppelsheim* in Hesse Darmstadt, together with "the bones of

* Lyell's *Student's Elements*, p. 207.

† See *ante*, p. 91.

a large *ape* of the *Gibbon* tribe, the most Northerly example yet discovered of a quadrumanous animal."

d. Beds of the same period near *Athens* have yielded—remains of *Dinotherium, Mastodon, Hipparion,* two species of *Helladotherium* (a *Giraffe*), *Antelope,* and other mammalia, some living and some extinct, together with those of *rodents* akin to the Marmot and Beaver, an *Ape* allied to living species, a *carnivorous animal* intermediate between the Hyæna and the Civet, and a *ruminant* between the Antelope and the Goat.

e. The Upper Miocene Beds of *Switzerland* have been called "the *Molasse,*" from the French word "*mol,*" because of the *soft* nature of their material. They occupy the country between the Northern portion of the Jura range and the Alps. The group is divided into the *Lower,* a *marine* series of beds* which correspond with the "*Faluns*" of France, and the *Upper, fresh-water,* which are best shown at *Œningen,* in the valley of the Rhine between Constance and Schaffhausen.

e'. The *marine* deposits of the Upper Miocene beds of the "Molasse" occur at a height of 2,470 feet above the sea. Their *mollusca* agree in the main with the mollusca of the French "*Faluns*": about 90 species of *plants* occur in these beds, although almost entirely absent in other corresponding beds of the Continent.

e''. The *fresh-water* beds of *Œningen* consist of a series of marls and limestones, often finely laminated, and formed apparently by very slow deposition, and abound in remains (frequently beautifully preserved) of *fish, insects,* and *plants,* with a few characteristic *mammalia* and *reptiles*: these

* Overlying Lower Miocene beds, alluded to at p. 91.

organic remains have chiefly been derived from two quarries, situated respectively at 550 feet and 700 feet above the level of the neighbouring Lake of Constance.

Professor Heer of Basle has identified more than 500 species of plants and upwards of 800* species of insects from these beds, which he considers to have been formed in a lake, to which these plants and insects, together with other remains, were brought down by some considerable river, and embedded in a kind of travertine formed at the bottom by calcareous matter supplied in solution by springs.

The *mammalia* include a peculiar form of *Mastodon* (*Tapiroides*, "Tapir-like"), an animal allied to and about the size of a *Fox* (*Galecynus*† *Œningensis*), an extinct kind of tailless *Hare*, and a ruminant, *Palæomeryx*, etc. The *reptilia* include an aquatic *Salamander* (larger even than its great living representative the Salamander of Japan), and numerous *Tortoises*. The *fish* include the *Pike*, the *Tench*, the *Roach*, and a multitude of small fishes.

f. In the *Siwâlik Hills of India*, which lie at the Southern foot of the great Himalayan chain, an important series of deposits (discovered and investigated by the late Dr. Falconer and Sir Proby Cautley) answer to the Upper Miocene beds of Europe. They consist of marls and sandstones, and contain a great variety of fossil *mammalia* and *reptiles*, and about 15 species of *fresh-water shells*: of the last, 11 are extinct, and four still live in Indian rivers.

* The entire list of Swiss species of insects from the Lower and Upper Miocene together numbers 1,322. Professor Heer has examined 5,080 specimens from Œningen alone.

† "Weasel-Dog." Discovered in 1829 by Sir Roderick Murchison, and deposited in the Museum of the Geological Society.

The *mammalia* include many genera which occur in the European beds of the same age, and comprise—*Hipparion*, several *Tapiroids*, an extinct *Hippopotamus*, two species of *Mastodon*, two of *Elephant* (the earliest occurrence of this genus), three other *Elephantine proboscidians* intermediate between Mastodon and Elephant, and a species of *Hog*; of *ruminantia*, the *Giraffe*, *Antelope*, *Stag*, *Camel* (the earliest known), and a remarkable gigantic new form, the *Sivatherium* (the Indian god "Siva's beast"), a four-horned animal, allied to the Prongbuck of North America*; and of *carnivora*, *Machærodus*, *Hyæna*, an *Ursine* animal, and a large genus allied to the *Otter*.

Of *reptilia*, have been found in the same bed—several *Crocodiles* of huge dimensions (one still existing in the Ganges), another *saurian* still living in India, and a colossal *Tortoise* (*Colossochelys Atlas*), the shell of which was 12 feet 8 inches long and 8 feet in breadth, the entire length of the animal having been about 18 feet, and its height 7 feet. A large *Ostrich* was associated with the other remains.

f. Numerous fossils of the Siwâlik type have been found in Perim Island in the Gulf of Cambay (Western India), and with them a *Dinotherium*, clearly identifying the deposit with the Upper Miocene of Europe.

g. In *North America*—in North Carolina, Maryland, Virginia, and Delaware—occur strata of the age of the Upper Miocene of Europe and of the earlier beds of the English Crag, and combining the two, as shown by characteristic *molluscan genera*; which include a very peculiar

* Described and figured in *Falconer's Palæontological Memoirs and Notes*, by Dr. C. Murchison, 1868, vol. i. pp. 247–279; also in an instructive article by Dr. J. Murie (with plates of the restored animal), in *Geological Magazine*, vol. viii. (1871), pp. 438–448.

gasteropod, the *Fusus quadricostatus* of Maryland. Many of these genera are still living, but are confined to the New World, to the Western side of the Atlantic.

41. The PLIOCENE System—

Is mainly represented in this country by beds which occur in Essex, Suffolk, and Norfolk, and which have received the provincial name of "*The Crag.*" The System is divided into the *Older Pliocene* and the *Newer Pliocene.*

42. The *Older Pliocene* includes the *White* or *Coralline Crag* and the *Red Crag.*

It was stated in the last Section that certain strata in the Eastern districts of the United States agree in some of their fossil forms severally with the Upper Miocene beds of the Continent and with the oldest Crag beds of this country. In the neighbourhood of Antwerp, there are strata which underlie, and are therefore older than, beds of the same age as the Red and Coralline Crags of our Eastern Counties: they are called the "*Black Crag*" or "*Diestein.*" These American and Belgian strata may therefore, in combination, represent a *passage* time uniting the Miocene and Crag periods.

a. The *White* or *Coralline Crag* (or such of it as was left after a great denudation which preceded the deposition of the Red Crag) has a very limited horizontal range, being only found in the county of Suffolk. It has a gross thickness variously estimated at 83 feet* and 60 feet.† Professor

* Professor Prestwich, *Journal of Geol. Soc.* 1871, p. 120.

† Messrs. Searles Wood, jun. and F. W. Harmer, *Introductory Outline, Supplement to Crag Mollusca, Palæont. Soc.* 1874, page ii.

Prestwich has estimated the depth of the sea in which these beds were deposited at from 500 to 1000 feet*; Messrs. Searles Wood, jun. and Harmer at less than 300 feet.

The Formation has been termed the "*White*" Crag because of the absence of the ferruginous stain which characterizes the Red Crag, and the "*Coralline*" Crag because of the *Corallines* (really *Polyzoa*) with which its middle portion abounds.

a'. The number of species of marine shells which the Coralline Crag has yielded (after eliminating "derived" † and doubtful species) amounts to 391; of which 142 (or 36 per cent.) are extinct,‡ and 249 (or 64 per cent.) existing§: a proportion indicating a nearer approach than in the latest beds of the Miocene System to the molluscan fauna of the Recent period.

a''. The lowest bed of the Formation contains *phosphatic nodules*,‖ which, in all probability, had an origin in animal matter; also numerous "derived" fossils of *terrestrial* and *marine mammals*, etc., of the same character as, but less numerous than, those found in similar beds in the Red Crag, to be described in the next Section. These remains, with little doubt, are for the greater part originally of the *Miocene* age, although some (such as seven vertebræ of a Whale

* *Journal of Geol. Soc.* 1871, p. 135.

† "Derived" fossils (as stated at page 67) are fossils which have been washed out of their original beds by denudation, and re-deposited in beds of subsequent formation.

‡ The word "extinct" in this instance, and whenever used in reference to the Crag beds, is to be understood as meaning, *not known as living*.

§ Searles Wood—*Supplement to Crag Mollusca, Palæontological Society*, 1874, p. 219. These numbers do not quite agree with those given by Professor Prestwich in paper previously cited, p. 128.

‖ Professor Prestwich, *Journ. Geol. Soc.*, 1871, pp. 119–121, 125, 133.

found united) are certainly those of animals which lived in the Coralline Crag period. The presence of a large transported boulder of porphyry in this lowest bed is an evidence that icebergs traversed the seas of this age.*

b. The *Red Crag* (so called on account of its deep red or ochreous colour, due to the presence of the oxide or rust of iron) consists in some places of numerous thin *laminæ* of sand and shells, generally very much inclined, the effects of strong currents and water-action during deposition, and perhaps of foreshore sub-aërial or tidal conditions of accumulation. Its total thickness does not greatly exceed 25 feet. It occurs chiefly in Suffolk and in Essex, and has a much wider spread than the Coralline Crag (which it sometimes encircles and "overlaps"), covering an area of about 300 square miles.

b'. After eliminating 87 "derived" species, the marine shells of the Red Crag number 248; of which 69 (or about 27 per cent.) are extinct, and 179 (or 73 per cent.) are recent.† The *molluscan fauna* includes a great abundance of a reversed form of the existing Whelk (*Trophon antiquus*, var. *contrarius*), the whorls turning from left to right, and which preceded the dextral form of modern seas: the sinistral form is still found in a living state, although rarely. Another very characteristic *gasteropod* is the *Voluta Lamberti*; which occurs first in the Miocene marine beds of the Continent, but is not found in any beds later than those of the Crag.

b''. The *phosphatic bed* at the base of the Red Crag is of more important development than that of the Coralline Crag.

* Professor Prestwich, *Journ. of Geol. Soc.*, 1871, p. 117.

† Lyell's *Student's Elements*, p. 183.

Its thickness varies from 6 to 18 inches, and the nodules and organic remains frequently contain as much as 60 per cent. of phosphate of lime, and are valuable as manure.

The organic remains of the phosphatic bed may be divided into three classes:—

I. Those which (as indicated by their condition) are of the age of the deposit, such as—*Mastodon* (two species), *Elephas meridionalis* (which now first appears, and which was probably the largest species of the whole tribe), *Rhinoceros Schleiermacheri*, *Tapirus priscus*,* teeth of some *ruminants*, and the bones, etc. of *Cetacea*.

II. Those which have been "derived" from *Miocene* beds, including—*Mastodon*, *Rhinoceros*, *Tapir*, *Hipparion*, *Hog*, several species of *Deer*, a *Canine* animal (?), *Beaver*, a marine *mammal* of the genus *Halitherium*, tusks of *Walrus* (some of immense size), numerous teeth of *Seals* of various species, including one now represented by the *Manatus* ("Sea-cow"), etc.

III. Those which have been "derived" from the Eocene (London Clay), of which may be mentioned—the ear-bones of *Whales* (*Balænodon gibbosus*), a *carnivorous Whale*, a genus allied to the *Sperm Whale*, *Dolphins*, *Porpoises*, *Sharks* (some of colossal size, *Carcharodon*†), and other *fishes*, *Turtles*, *Crabs*, *Wood* (sub-tropical?) sometimes beautifully silicified, etc.‡

* The *Tapir* is now only known as living in America and Eastern Asia.

† A tooth in the possession of the Author represents a triangle of which the base measures $5\frac{6}{10}$ inches, and each side $6\frac{6}{10}$ inches: this is rather larger than a tooth in the Hunterian Museum, London; which Professor Owen, upon a comparison with teeth of existing Sharks, has concluded must have belonged to a Shark 60 feet in length!—*Palæontology*, p. 132.

‡ These marine remains are only provisionally assigned to the London Clay.

b'''. Organic remains of older beds, such as the Chalk and Lias, and included masses of Coralline Crag, also occur, indicating great denudation, sometimes combined with ice-action, during the Red Crag period.

b''''. Much ice-borne material, including unrolled blocks of flint, some measuring 2 feet by 18 inches, in this lower bed, indicates the frequency of icebergs at any rate in the early Red Crag Seas; and there are data in higher deposits which justify the supposition of icebergs having stranded on the shores of a little later time.

c. In Italy, at the foot of the Apennines, both on the Adriatic and Mediterranean sides, are Tertiary strata forming a line of low hills between the older chain and the sea. These are chiefly composed of strata equivalent to our Coralline and Red Crags, the mollusca to a considerable extent agreeing therewith: but overlying these, are beds, probably agreeing with our Newer Pliocene; while the lowest beds are perhaps scarcely more recent than the Miocene age. Certain beds in the Upper Val d'Arno,* to be hereafter described,† are probably also of the Crag period.

43. The *Newer Pliocene* consists of the *Norwich* or *Fluvio-Marine* Beds and the *Chillesford* and *equivalent* beds.

a. The *Norwich Crag* takes its name from its occurring in its greatest development in the neighbourhood of that city. It consists of incoherent sand, loam, and gravel, and contains shells, in the main marine, but including as many as 20 fresh-water and land species. Its beds must have accumulated at or near to the mouth of a river or on an area

* Lyell's *Student's Elements*, p. 189. † See forward, p. 104.

subject to the influences of tidal and river-current alternations: hence they are also called the "*Fluvio-Marine*" beds.

"An entire skeleton of *Mastodon* is said to have been discovered in these beds (at Horstead, Norfolk) some years since," * the latest bed in which the remains of *Mastodon* have been found.

The marine *mollusca* consist of 111 species, of which 18 (nearly 17 per cent.) are extinct, and 93 (or more than 83 per cent.) existing.†

The beds occur in patches resting upon the White Chalk with Flints, and seldom exceed an aggregate thickness of twenty feet. The eroded surface of the Chalk is often profusely bored by the bivalve *Pholas crispata* of the Crag Seas,‡ the shell frequently remaining in the crypt. The species is identical with the living one.

"At their junction with the Chalk, there invariably intervenes a bed called the 'Stone-bed,' composed of unrolled chalk-flints," § mingled with the remains of *Mastodon Arvernensis* (its last appearance), *Elephas meridionalis*, two extinct species of *Deer*, etc. It is to be noted that no phosphatic nodules occur in this bed, and that, whereas the similar beds in the Coralline and Red Crags contained "derived" fossils of the Miocene and Eocene ages respectively, the mammalian remains of the Norwich bed are wholly of Pliocene species, including (besides some forms previously enumerated as occurring in older beds)—*Bear*, *Hyæna*, a *Feline* animal allied to the *Leopard*, *Horse*, *Ox*, *Trogontherium* ("gnawing beast," akin to a very large Beaver), *Otter*,

* Prestwich, *Journal of Geol. Soc.*, 1871, p. 459.

† Searles Wood's *Supplement*, *Palæontological Society*, p. 219.

‡ Prestwich, *Journal of Geol. Soc.*, 1871, p. 460.

§ Lyell's *Student's Elements*, p. 174.

Water-Rat, Field-Mouse, and *Birds**: some of these forms have been found for the first time in these beds. The early discovery therein of mammalian remains led to the Norwich Crag being formerly called by Mr. Charlesworth the "*Mammaliferous Crag.*"

b. The *Chillesford* and *equivalent Beds* have a much greater horizontal extent than the Norwich Crag: they occur not only at Chillesford between Woodbridge and Aldborough in Suffolk, but in Norfolk (in some Sections in which county they are seen to overlie the Norwich Crag), and in many other localities; and occasionally they "overlap" older Crag beds. They reach a thickness of 20 feet, and consist of layers of sands and laminated clays, all very micaceous.

These beds are of varying marine and fluvio-marine (or *quasi*-estuarine) character. The skeleton of a whale has been found in the upper bed. Of 87 species of marine shells, 14 (or 16 per cent.) are not known as living, and 73 (or 84 per cent.) are still existing.†

c. About 10 miles above Florence, a part of the valley of the river Arno, which is narrow and deep, is called the Upper Val d'Arno, and was probably a lake at the time that the valley below Florence was an arm of the sea. The deposits in the area of this lake reach a thickness of some 750 feet; of which, the lower 550 feet, consisting of dark clay with layers of lignite, are of the Older Pliocene age. The rich *flora* of these beds has no parallel in the Pliocene Formations of this country: it indicates a climate somewhat colder than, and a period immediately following, that of the Miocene period. The upper 200 feet are of Newer Pliocene age, and contain *mammalian* remains of the same

* Professor Prestwich, *Journal of Geol. Soc.*, 1871, p. 456.

† Searles Wood's *Supplement to Crag Mollusca*, p. 219.

general character as those of the Norwich Crag and Norfolk Forest Bed.*

d. In Sicily, the Newer Pliocene deposits occur in greater development than in any other part of Europe. They cover nearly half the Island, reach an aggregate thickness of 2,000 feet, and in the centre of the Island an elevation exceeding 3,000 feet. "Since the accumulation of these beds, the whole cone of Etna (11,000 feet in height, and 90 miles in circumference at its base) has been slowly built up," † an operation involving the lapse of very many thousands of years. The *mammalian* remains agree with the Geological era of the beds. The *molluscan* remains are chiefly remarkable for their beautiful preservation: many species are still living in the adjacent seas; although, as it would appear, these species are really older than the Island itself.

e. In newer Tertiary deposits of North America, the remains of a *Mastodon* occur, the teeth of which partake of the form of the teeth of *Dinotherium.*

f. In Pliocene deposits in Piedmont, the skeleton of a *Mastodon* has been found, the teeth of which are intermediate between those of the American form and the common species *Arvernensis.*

A comparison of the numbers of species of *marine mollusca* of the several British Crag Formations ‡ will show—that, of 391 species in the Coralline Crag, 36 per cent. are extinct; of 248 species of the Red Crag, 27 per cent. are extinct; of 111 species of the Norwich Crag, 17 per cent. are extinct; and of 87 species of the Chillesford Beds, 16 per cent. are

* See forward, pp. 107–8. † Lyell's *Student's Elements*, p. 186.
‡ See *ante*, pp. 99, 100, 103, and 104.

extinct—indicating a gradual but marked approach in identity of species to the mollusca of existing seas.

The general character of the mollusca of each of these Crag periods, and their progressive changes, have a further significance. The mollusca of the Coralline Crag have a very noticeable affinity to the living mollusca of the Mediterranean, indicating nearly similar climate and conditions: but a gradual departure from such a similarity is observable in each successive Formation (and even between the upper and lower portions of a Formation), until, in the Chillesford Beds, comparatively few species having Mediterranean affinities remain, and a climate is indicated probably not very different to that of this country at the present time.

There is some variation of opinion as to the identification and classification of the English Crags and some subsequent Formations:—

Professor Prestwich considers that the Norwich Crag is synchronous with the Red Crag, and that the lithological and other differences are only of local origin; also that the Chillesford beds, wherever situated, are simply an upper and deeper-sea member of the same Formation.*

Mr. Searles Wood is of opinion that, while there is a complete separation of the Coralline and Red Crags, "the Red and Fluvio-marine Crags, and their over-lying Chillesford clay and sand, can be regarded as only one deposit, constituting in England the Upper Crag, as the Coralline does the lower; and that the triple division of the Crag, which has for so many years been assumed, must be abandoned." †

* *Journal of Geol. Soc.*, 1871, pp. 453–461.

† *Supplement to Crag Mollusca, Pal. Soc.*, p. 198.

Biding the settlement of disputed points, I have adopted the arrangement in my text, subject to any future needed modifications.

D. Quaternary or Post-Tertiary Strata—Cainozoic Life Period (*continued*).

44. The Post-Pliocene or Pleistocene System.

With this System, great changes were inaugurated: the *fauna* became more assimilated to that of the Human era, and towards the close of its period *Man* himself appeared; whilst the *flora* differed little from the indigenous flora of the Recent age.

The System is marked by the intervention of a great Glacial epoch, which affected more or less the whole area of this country and the greater part of the Northern Hemisphere, materially altering the surface contour and the relative disposition of land and water.

This Glacial epoch led the late Professor Phillips to classify the Post-Pliocene Formations as—*Pre-Glacial*, *Glacial*, and *Post-Glacial*.*

45. The *Pre-Glacial* period is most importantly represented in this country by Formations exposed in the cliffs and upon the shores of the Northern coasts of Norfolk; which there immediately underlie thick deposits of the earliest phase of the Glacial Period. These Formations, in ascending order, are distinguishable as†:—

a. The *Weybourne Sands*, a marine deposit.

b. The *Forest Bed*, which consists of two distinct por-

* See his Work on "*The Rivers, Mountains, and Sea-coast of Yorkshire*," 1853; and *Guide to Geology*, 5th edition, 1864, p. 147.

† Lyell's *Antiquity of Man*, 4th edition, 1873, p. 260.

tions—the lower, a land-surface bed; and the upper (sometimes called the "Elephant Bed"), an Estuarine deposit.

c. The *Westleton Sands* and *Shingle**—for the most part marine.

a'. The Weybourne Sands (which near Cromer adjoin laterally the Forest Bed, underlie the Estuarine portion of the same, repose upon the Chalk, and in such position have been called the "Iron Pan," being ferruginous) have been considered by Professor Prestwich to be equivalent to the Norwich Crag,† while Mr. Searles Wood calls them the "Lower Glacial Sand."‡ Sir Chas. Lyell§ says that these Sands are closely allied to the Norwich Crag and Chillesford Beds, but are distinguished by the presence of the bivalve *Tellina Balthica*; which now first appears, but occurs in profusion in all subsequent Formations down to the Recent period: on which account, he has concluded that they are nearly coeval with the Land Forest Bed, but slightly newer, Elephants' teeth having been found in them. The *mollusca* generally vary little from the mollusca of existing seas, including only three species not known as living.

b'. In the lower, the land-surface, portion of the Forest Bed, are the remains of an actual forest. At the base of the cliff near Cromer, stretching for 40 miles along the shore, and a considerable way under the sea, is a bed in which occur numerous upright stumps of trees, some of them two to three feet in diameter, with their roots spreading out horizontally in the same position as when they were growing (as they did grow) upon the very site upon which

* Professor Prestwich, *Journal of Geol. Soc.*, 1871, p. 461.

† *Ibid.* pp. 459–60.

‡ *Supplement to Crag Mollusca, Pal. Soc.*, p. 151.

§ *Antiquity of Man*, 1873, p. 259.

they are now found. This forest must have existed through a long period of time; as is indicated by the size of the tree stumps which remain, and by the vast accumulation of vegetable matter about and above them.

The *trees* and other *plants* of which the remains have been found in these beds are of kinds familiarly growing in this country at the present time, viz.:—the *Scotch* and *Spruce Firs*, *Yew*, *Oak*, *Alder*, *Birch*, common *Sloe* or *Black-thorn*, *Buckbean*, *Osmunda Regalis* (*Fern*), *Hornwort*, *White* and *Yellow Water Lily*, *Pondweed*, etc. The *mollusca* consist wholly of fresh-water and land shells of existing species.

The *mammalia* of which remains have been found in earlier Formations and which again occur in these beds are*:—

Machærodus (sabre-tooth).
Elephas meridionalis.†
Rhinoceros Etruscus.†
Hippopotamus.
Horse.
Hog.
Ursus Arvernensis.†
Trogontherium (an immense Beaver).†
Beaver.
Shrew Mouse.
Water Rat.

Those which appear for the first time in these beds:—

Elephas antiquus.‡
„ *primigenius*.‡
Rhinoceros megarhinus.
Bos primigenius.
Cave Bear.
Wolf.
Fox.
Musk Rat.
Mole.
Cervus megaceros (great horned) —(gigantic Irish Deer).
„ *Polignacus*.†
„ *Sedgwickii*.†
„ *carnutorum*.†
„ *verticornis*.†
Red Deer.
Roebuck.

* This list is taken from Lyell's *Antiquity of Man*, 1873, p. 257—supplied by Professor Boyd Dawkins.

† Not found in later beds.

‡ Of these two Elephants, *E. antiquus* was the larger, although not so large as *E. meridionalis*. *E. primigenius* was larger than any living

b''. The overlying Estuarine bed consists of variable clays and sands, interspersed by layers and patches of plant-remains; which afford evidence that its formation, under altered conditions, immediately followed that of the bed beneath it.

The Estuarine bed contains the remains of a *Walrus*, *Narwhal* (or Sea-Unicorn), *Whales* of various species, and several *fish*.

c'. The Westleton Sands and Shingle * attain a thickness of from 30 to 40 feet. Near Cromer, they interpose as a thin band between the Estuarine portion of the Forest Bed and the lowest Glacial "Till"; but inland, where the Forest Bed and Weybourne Sands are wanting, they reach their maximum thickness, and immediately overlie the Chillesford Beds. It is a question, indeed, whether they are not identical with the Weybourne Sands, and whether the beds thus differently named are not really earlier and later portions of one Formation, divided locally by the intercalation of the Estuarine deposits.†

The lowest of these beds of the Pre-Glacial age represents a land the surface conditions of which were much the same as those of the present day, with perhaps a somewhat milder climate. The trees and plants are familiar to us,

species. *E. antiquus* had long straight tusks, *E. primigenius* curved tusks. The remains of Elephants are very common in this country: about 1812, an Oyster-bed was discovered off Happisburgh, within the range of the Forest Bed on the Norfolk coast, from off which the fishermen brought up in their dredges in about 14 years as many as 2,000 Elephant molars, representing some 400 animals.

* The "Bure Valley Beds" and "Pebbly Sands" of Messrs. Searles Wood, jun. and Harmer—see Note to *Introduction to Supplement to Crag Mollusca, Pal. Soc.*, 1872-4, page xv.

† *Vide* Lyell's *Antiquity of Man*, 1873, 4th edit., pp. 259–261, fig. 32.

although the animals are strange. Then flourished the largest Elephant the world has ever seen. The sea gently washed the shores of that forest land, and for a time all was luxuriance and peace. At length, a slow subsidence took place, and the area of the forest became the area of an estuary. A colder climate gradually set in, glaciers descended from the high lands, and the woolly-coated Elephant for the first time appeared. Age after age passed, and then the ocean engulphed the whole. Again a long lapse of time, succeeded by Glacial elevation and Greenlandic ice-conditions, next to be described; resulting in the deposition of the overlying Glacial Clays and "Contorted Drift" of the Norfolk cliffs.

46. The *Glacial Period* was characterized upon the area of this country by *three* remarkable series of changes and phenomena, and may be divided into eras as follows:—

a. The first era—during which a considerable elevation occurred, accompanied by an extreme arctic climate.

b. The second era—during which there was a great subsidence, the area of the depression being occupied by a stormy ocean, studded with ice-islands, and traversed by icebergs.

c. The third era—during which a commensurate elevation and emergence took place, a return to terrestrial conditions, the latest appearance of glaciers in this country, and a gradual modification of climate.

a'. The amount of elevation during the first era has not been ascertained; but it is known that the mountains of Westmoreland, Wales, Scotland, and Ireland, were much

higher than they are now, and that many of what at this time are only hills were then mountains.

a''. The climate was so severe, that all valleys were filled with glaciers, the mountains and lowlands alike covered with ice, and the whole area of this country and the greater part of Europe enveloped in one great almost unbroken ice-sheet: this was in a state of slow but constant motion, and was continually carving out and grinding away the rock-surfaces beneath; so that valleys were deepened, and in some instances excavated, by this agency, and often immense lake-basins were scooped out by the action of ice alone.*

Vast accumulations of mud (studded with fragmentary masses of rock) and gravel were the result of this great ice-action; and hence have probably been derived the older and sometimes separated portions of the Boulder Clay.

b'. The era of elevation and arctic glaciation was succeeded by an era of great subsidence, probably of 2,300 feet.† This subsidence occurred over the whole of the British area (with the exception of a small Southern portion), and over a great part of Central Europe, extending Eastwards into Russia, and North and South from the Northern shores of the Baltic nearly to the Alps.

b''. The area of subsidence was occupied by an ocean, studded with islands covered with snow and glaciers, rendered turbid by the ice-mud of the previous age, and traversed by icebergs, the ruins of ancient glaciers,‡ laden with rock-masses, gravel, sand, and mud: these, as the icebergs melted, were strewn along the sea-bottom;

* Professor Ramsay,—*Journal of Geol. Soc.*, 1862, p. 185; and "*Physical Geology of Great Britain*," pp. 168–177.

† Professor Ramsay, *Journal of Geol. Soc.*, 1852, p. 372.

‡ See Pt. I. Sec. 15, *c*.

and hence were formed the more recent portions of the Boulder Clay and Glacial Drifts and Gravels, which once covered nearly the whole surface of the country North of the Thames, and patches of which still commonly cap the high grounds of many inland districts.

b'''. The *mollusca* of the Glacial deposits are not numerous, but comprise upwards of 30 species now found only in Arctic Seas: among them are—*Astarte Borealis, Cyprina Islandica, Leda Arctica, Pecten Islandicus, Saxicava rugosa, Scalaria Greenlandica*, etc. An upper bed of the Glacial series occurs at *Bridlington* in Yorkshire, which has yielded about 60 species of mollusca, about one-third being Arctic: of the whole number, only three species are not known and two doubtfully known as living.

c'. On to the third era the Arctic conditions continued, but became gradually modified during the slow elevation and emergence of the subsided area. Glaciers occupied the valleys of mountainous regions; but diminished by degrees, and ultimately disappeared. The land-surface again teemed with vegetation; and mammalian life-forms migrated in abundance from the Continent, as yet unseparated from Britain.

These series of phenomena (of elevation, depression, and re-elevation) during the Glacial period, followed as they were, after intervals, by the separation of Ireland from Great Britain, and Great Britain from the Continent, fashioned and left the general surface contour of this country much as it is now: yet important physical changes have since occurred—mountains and hills have been wasted, some valleys have been excavated and others enlarged and

deepened, thick fluviatile deposits have accumulated and have been subsequently channelled by existing streams, rivers in some instances have ceased to flow and the courses of others have been altered, whilst coast lines have greatly changed.

[NOTE.—Sir Chas. Lyell has included the Pre-Glacial Formations and the Glacial Formations of Norfolk and Bridlington in the Newer Pliocene System and in the Tertiary Division.* Mr. Searles Wood would abandon the Post-Tertiary Division altogether, and include all Formations between the Norwich Crag and the Recent Period in the Tertiary Division.† I have followed the older classification of Professor Phillips,‡ Sir Charles Lyell,§ and others.]

47. The *Post-Glacial* period.

The great characteristic of this period is, that, so far as we are at present assured, it witnessed the *commencement of the human era.*|| While all its *mollusca* are of existing species, the *mammalian* remains represent many animals of extinct kinds: these remains are stratigraphically associated with

* Table of Strata, *Student's Elements*, 1874, p. 109.

† *Supplement to Crag Mollusca, Pal. Soc.*, p. 201.

‡ *Guide to Geology*, 5th edition, 1864, p. 147.

§ *Elements of Geology*, 1865.

|| Mr. James Geikie, in his recent work on the "*Great Ice Age*," would assign an *Inter-Glacial* position to the earliest known human period; and the discovery of a human *fibula* in the Victoria Cave near Settle in Yorkshire, in a deposit overlain by an *apparently* Glacial clay, has been regarded by some as conclusive evidence that Man lived in this country prior to the last Inter-Glacial period: but Mr. Evans, in his *Presidential Address* at the Anniversary Meeting of the Geological Society of the present year (1875), after alluding to these views, stated his opinion that present *data* are insufficient to enable us to carry back the human era into Pre-Glacial times.

the works and the remains of *Man*; indicating that such extinct animals had lived contemporaneously with him.

The remains of extinct animals which have been found in this Country and on the Continent associated with the works and the remains of Man are as follows *:—

Machærodus latidens—Sabre-toothed Lion.
Felis leo, var. *spelæa*—Cave Lion.
Hyæna spelæa—Cave Hyæna.
Ursus spelæus—Cave Bear.
Elephas antiquus—Ancient Elephant.
„ *primigenius*—Elephant of the first kind ("Mammoth," or Woolly Elephant).†

* Lyell's *Antiquity of Man*, 1873; and Professor Boyd Dawkins—*Journ. of Geol. Soc.*, 1872, pp. 410–445; and *Cave Hunting*, 1874, pp. 360–1.

† A carcase of *Elephas primigenius*, which had been perfectly preserved by the ice, was exposed upon the fall of a frozen cliff at the mouth of the Lena in Siberia in 1799. Wolves devoured the flesh, but the skeleton and a fragment of the hide are in the Imperial Museum at St. Petersburgh. The hide was covered with coarse hair, forming a shaggy mane about the neck: under the hair was a woolly coat, eminently adapted for a protection against cold. Another entire Mammoth, having tusks 8 feet in length, was found in a half-frozen condition in the Russian river Indigirka in 1846; as graphically described by Benkendorf—see notice by Professor Boyd Dawkins in *Popular Science Review*, July, 1868. The tusks of these animals are abundant in Northern Russia, and so preserved by the ice as to retain their quality as good ivory: they form an important article of commerce with this country. A head of *E. primigenius* in the British Museum, found in 1864 at Ilford in Essex, is adorned with tusks 10 feet 6 inches in length, and 25 inches in circumference at the thickest part. A tusk dredged up at Dungeness is described by Professor Owen as measuring 11 feet in length. An imperfect molar of the same species (in the possession of the author) from the River Gravel near Kettering, Northamptonshire, weighed when found 14 lbs. Teeth, tusks, and bones of Elephants, representing more than 20 individuals of the species *antiquus* and *primigenius*, have been obtained from the gravels of the Nene valley between Northampton and the Fens, a distance of about 45 miles.

Rhinoceros tichorhinus—a Woolly-coated Rhinoceros.*
„ *leptorhinus*—a Fine-skinned Rhinoceros.
„ *hemitœchus*—a Slender Rhinoceros.
Hippopotamus major—Great Hippopotamus.
Cervus Megaceros—"Large-horned" (the great Irish Deer).
„ *Browni*—an Extinct Fallow Deer.
Bison priscus—Extinct Bison.
Bos primigenius—Ox of the first kind.
Equus spelæus—Cave Horse.
Rupi-capra Christolii—a kind of Chamois.
Lepus diluvianus—an Extinct Hare. And others.

The following are still-existing species of *mammalia* which in the same age inhabited, but are not now indigenous to, this country:—*Leopard, Lynx, Glutton, Arctic Fox, Wild Boar, Reindeer, Musk Buffalo, Grizzly Bear, Brown Bear, Wolf, Beaver, Horse,* the *Lagomys* or *Calling* or *Tailless Hare,* the *Ermine,* the Norwegian *Lemming,* the Greenland *Lemming,* the *Spermophilus* (*Pouched Marmot*).

During the same period, there also lived on this area numerous animals of kinds still inhabiting Great Britain.

Contemporaneously with the animals named in the foregoing lists as having lived in this country and in Europe, others having entirely different characteristics flourished in South America; and it is remarkable that these consisted of animals allied to genera which exist now only in that region, such as—the *Mylodon* ("mill-tooth") and the *Megatherium* ("great beast"), colossal *Sloths* (a skeleton of the latter in

* "The discovery of the carcase of the *Tichorhine Rhinoceros* in frozen soil, recorded by Pallas in his '*Voyages dans l'Asie Septentrionale*,' 1793, showed the same adaptation of this, at present tropical, form of quadruped to a cold climate, by a twofold covering of wool and hair, as was subsequently demonstrated to be the case with the Mammoth."—Professor Owen, *Palæontology*, p. 396.

the British Museum measuring 18 feet in length); and the *Glyptodon* ("sculptured tooth"), as gigantic an *Armadillo*, of which an individual of a "smaller species" measures 9 feet in length and 7 feet across its dorsal armour following the curve.*

In like manner, fossil remains of *marsupialia* (including immense forms of the *Kangaroo*, the head of one in the British Museum measuring three feet in length,) are found in Australia; where only (and in Van Diemen's Land, New Guinea, and adjacent islands) living marsupials occur.

The earliest indications of the presence of *Man* consist of *implements* or weapons made (by repeated chipping blows) of flint-stones. The *Post-Glacial* Period, accordingly, has been also called the "*Palæolithic Period*"†—Greek, "*palaios*," old, "*lithos*," stone; the oldest Stone Period.

The Palæolithic Period has been sub-divided into—

a. The more ancient—the *River Drift* or *Gravel Period.*

b. The less ancient—the *Cave Period.*

a'. In the older division of the Palæolithic deposits, the River Gravels, no human bones have with certainty been discovered, but only the rudest forms of chipped flint-implements and flakes. These are generally associated with the teeth and tusks of *Elephants*, the teeth and bones of *Rhinoceros*, *Hippopotamus*, *Bear*, *Cave Lion*, *Cave Hyæna*, great *Irish Deer*, *Reindeer*, *Bison*, great *Ox*, *Horse*, or some of them.

In Gray's Inn Lane, London, 160 years ago, a fine flint-implement was dug up, and with it an Elephant's tooth.

* Owen's *Palæontology*, p. 427.

† Sir John Lubbock, *Pre-historic Times*, 1865, p. 2.

At Hoxne in Suffolk, at the close of the last century, several flint-implements were found; and in 1859, others at the same place. Since that date, many flint-implements have been discovered in the valley of the Ouse near Bedford, in the gravels of the rivers Lark and Little Ouse in Norfolk and Suffolk, in gravel at Fisherton near Salisbury, and near Reculvers, Kent, in several localities near Southampton and in Hampshire, in Kent, Surrey, Middlesex, and in many other places.*

a''. The chief localities on the Continent in which Palæolithic implements from the River Gravels have been found are the neighbourhoods of Abbeville and Amiens, in the valley of the river Somme, in France. Indeed, it was the inquiry, in 1858 and 1859, as to the implements found in the fluviatile deposits of these districts, that led to the determination of the true character of such implements, and of the Geological period to which they belonged.† They have since then been found in Greece, Italy, Spain, Palestine, at the Cape of Good Hope, and in India.‡

a'''. That these flint-implements are really the work of Man's hands is shown by the fact that, although some thousands of them have been collected, they present as to form only a few types or patterns. Moreover, many of them have been fashioned by alternate blows given on the one side and on the other side of each edge. They cannot, therefore, be the result of accidental fracture.

* Evans, *Ancient Stone Implements*, 1872.

† Professor Prestwich, *Philosophical Transactions*, pt. ii., 1860, p. 277; Mr. John Evans, *Archæologia*, vol. xxxviii., 1860.

‡ Evans—*Ancient Stone Implements*; and *Anniversary Address, Geol. Soc.*, 1875.

b'. Among the most important caves in this country which have been found to contain the remains of Man associated with extinct animals, are—Kent's Cavern and Brixham Cave, near Torquay; Wookey Hole, in Somersetshire; and the Long Hole, Gower, Glamorganshire.

The human works in these caves consist of chipped flint-implements and flint flakes or knives, and various objects in Reindeer's horn and bone—including (from Kent's Cavern) harpoon heads notched or barbed sometimes on one side and in some instances on both sides (and very like harpoon heads of the Esquimaux of the present day), an awl, a pin, and a veritable needle with an eye. No human bones of trustworthy authenticity have been discovered.

b''. The most remarkable caves on the Continent are those of Belgium and the South of France. In these have been found the skeletons of men, and with them, unpolished flint-implements, articles of bone, Stag's horn, and ivory, and absolutely works of art—a representation of a Reindeer carved on its own horn, similar carvings of other animals in horn, a Reindeer carved in limestone, and incised drawings of various animals on bones, and of the *Elephas primigenius* on a fragment of its own tusk, showing its peculiarities of shape and the curved form of its tusks, and indicating the shaggy character of its hide.*

In 1872, a human skeleton was found in a cavern at Mentone, associated with chipped flint-implements and the remains of animals of species living in Palæolithic times,† and under conditions seemingly implying a formal interment.

* *Reliquiæ Aquitanicæ*; Boyd Dawkins, *Cave Hunting*, etc.

† Lyell's *Antiquity of Man*, 1873, p. 143; *Geol. Mag.* 1872, pp. 272, 368.

It can be proved that during the Palæolithic period the area of the British Isles formed part of the Continent of Europe. At an earlier age (the Pre-Glacial), vast herds of Elephants of three species roamed over that area. By a great subsidence during the Glacial period,* the greater part of that area was sunk beneath the Ocean, while the remainder was covered with thick ice; so that all terrestrial animal life was either destroyed or driven away—no Elephants could possibly have remained. Two species, however (*E. antiquus* and *E. primigenius*), which had lived in older times, *re-appeared* in the Palæolithic period, after that area had again become land. They could only have come *overland* from the Continent. By the same route, also, in the same manner (*on foot*), and in the same Geological age, *Man* must have migrated to this country.† The Geological Formations on either side of the British Channel also indicate a former continuity.

There is little doubt that, during the same period, Africa was united to Spain at the Straits of Gibraltar, and to Italy across the narrow and shallow seas between Tunis (by Malta and Sicily) and Calabria; that animals migrated from Northern Africa to Southern Europe, and from Central Europe to Britain; and that, following geographical and climatical changes, certain species died out, while others receded Northwards. Professor Boyd Dawkins has suggested that the present tribes of Esquimaux are the representatives of Palæolithic Man, who also travelled Northwards during these changes.‡

* See *ante*, pp. 111–112.

† Professor Ramsay, *Physical Geology*, p. 250.

‡ *Cave Hunting*, pp. 353–359.

48. The RECENT Period.

In the earliest part of the Geological period "Recent," we have a junction of what perhaps strictly should be called the *latest Geological* age with the *earliest Archæological** age, and a continuing on of the great Geological sequence, through the border-land of "Pre-historic" ages, into Historic and Modern times.

a. During the earliest ages of the "Recent Period" the prominent use of flint or stone for weapons or implements continued, and Sir John Lubbock† has therefore called it the *Neolithic*‡ period. But a very considerable lapse of time marked the passage of the Palæolithic into the Neolithic period: of 48 species of *mammalia* recognized as living in Britain during the older period, only 31 lived on into the later; while, so nearly did the mammalian fauna of the latter time agree with that of the present day, that of those 31 species only *six* are not now living in this country.§

a'. Numerous Cave deposits of somewhat altered character belong to the *Neolithic* period; but the occasional use of caves for the purposes of human habitation was continued on into long subsequent times. The character of the skulls and other osseous remains of *Man* found both in these deposits and in those of the earlier Cave period, have furnished interesting data for the study of the physical and intellectual status of the remotely ancient representatives of our race.

a''. Chiefly in Denmark, but also in Scotland, in Devonshire, and in Cornwall, near the mouth of the Somme river

* Greek, "*archaios*," ancient, "*logos*," a discourse.

† *Pre-historic Times*, 1865, p. 2.

‡ Greek, "*neos*," recent, "*lithos*," stone—the more recent Stone Age.

§ Professor Boyd Dawkins, *Transactions of Prehistoric Congress*, 1868, p. 278.

in France, and in other places, occur, generally near a shore, mounds of shells (of no great thickness, but often covering very large areas), which evidently have been the refuse heaps* of unknown peoples, living in the Neolithic age. They fed chiefly upon the mollusca of the rifled shells of which these heaps were the receptacles, and which mainly consisted of Oysters, Cockles, Mussels, and Periwinkles.† A similar heap in the Island of Herm near Guernsey has been shown to be post-Roman in date.‡

a'''. Of this period also, are remains found in lakes in Switzerland and some other European countries, and in Ireland; which indicate the erection upon piles, away from the mainland, of dwellings and groups of dwellings (in one instance comprising some 300 wooden huts), so isolated evidently for the sake of security. The sites of these settlements are now sub-aqueous mudbanks (studded with the stumps of piles): from these have been obtained numerous objects of antiquity, showing that a rather advanced degree of civilization had ultimately been reached—such as different kinds of corn (evidencing agricultural cultivation), bones and teeth of such a character as to indicate the domestication of animals, and coarse woven fabrics. It is plain that the dates of these structures ranged into subsequent ages.§

In this period, the use of flint was greatly extended: in some districts, the surface is literally strewn with small and rude arrow and javelin heads, knives, skin-scrapers, saws, awls, etc., so that it has come to be called by some

* In Danish, "*kjökken-möddings*," or kitchen-heaps.
† Sir J. Lubbock's *Pre-historic Times*, p. 171.
‡ Evans, *Ancient Stone Implements*, p. 222.
§ See Lyell's *Antiquity of Man*, 1873, p. 18.

the "Surface Stone Period." By degrees, the manufacture improved, until some objects were wrought with such symmetry of form and such delicacy of chipping as to be beyond the reach of any known process of manipulation at the present time. Rubbing and grinding also were introduced, and such excellence was ultimately attained (especially in Denmark), that, for smoothness of surface and keenness of edge, the latest stone-hatchets are simply unsurpassable.

b. During the last-mentioned age, the use of metals such as Bronze or Iron was unknown: there came a time, however, when *Bronze* (not difficult of fusion) gradually, and doubtless from a small beginning, came into use for cutting-tools, and by slow degrees superseded Flint and Stone—not universally, however, but first in one place and then in another; so that, in regard to time, the use of the two kinds of materials may be said to have overlapped. The period during which Bronze was in use was of very long duration, and has been called the "*Bronze Age.*"

c. In due course, Bronze, in like manner, gave way to *Iron,* and the "*Iron Age*" was inaugurated. This age, commencing in Pre-historic times, has continued until now, linking the remote past with the present day; which, of a truth, is emphatically of the "*Iron Age.*"

Gold was in use for ornament in all but the earliest of these "Recent" ages, and probably for monetary purposes during the latest.

The classification of these Ages must not be regarded as of a strictly chronological character, but as evidencing only certain stages of civilization: it is probable that all three Ages—the Neolithic, the Bronze, and the Iron—may have

existed in different parts, even of Europe, at one and the same time*; and in some regions of the world, the Stone Age has reached down to a very recent period indeed.

The *fauna* of the Neolithic period and succeeding Prehistoric ages may be considered as identical with that of the present time, although some forms have disappeared: even during the Historic period, the great Struthious bird of New Zealand, the *Moa*, has died out; within the last three centuries, the *Dodo* of the Mauritius has become extinct; and during the present century, the *Great Auk*, an occasional visitant of British shores, has been lost. It is not impossible that new species, to supply the defections of these and the previous Post-Glacial ages, have been introduced; but of such a fact we know nothing, evidence upon such a question being unattainable.

Conclusion.

A contemplation of the long, varied, and for the most part continuous, series of the Earth's physical changes, as demonstrated by *Stratigraphical* phenomena, will leave upon the mind the prominent impression of the bewildering, the incomprehensible, lapse of time necessarily involved. Years, and cycles of years, are all inadequate to express the vast sum of the eons of the past—as compared with which, the completed history of the greatest river, of the widest continent, or even the long period of Man's hitherto career, would be but as a passing thought, or as a short episode in Nature's epic.

And a review of the *Life-History* of the Earth will be

* See Mr. J. Evans in *Ancient Stone Implements*, p. 2.

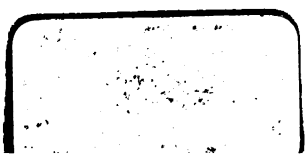
equally pregnant with significance. Not only does that Life-History also necessitate a lapse of time of incalculable vastness; but it exhibits, through all its periods down to the Recent age, an ever-accelerating advance, by an infinity of variations and developments, in the multiplicity of Life-Forms, and in the complexity and completeness of their organization.

In the all but formless *Eozoon*, we have the earliest known trace of animal life; and we follow on—to the hardly advanced and perhaps doubtful *Oldhamia*—thence, to minute sponges, obscure annelids, humble mollusca, proto-crustaceans—on, to more and more organized animal structures, to the variation and advancement of pre-existing forms, and to the introduction in ever-increasing numbers of newer types. We trace the advent, the culmination, the decadence, and the disappearance, of whole families of genera; and we note their re-placement by others of higher grade. We recognize a general, although perhaps irregular, advance, in animal organization, locomotive power, and perceptive or instinctive capacity; and we see how, when new classes of organisms appear, that these bear, as it were, lingering traces of affinity (either dormant or active) to other and older types. Thus—the earliest fishes, in their armour-coating, bear a strong resemblance to preceding crustaceans; the earliest reptiles (*Archegosauri*) have a great affinity to fishes; and reptiles themselves foreshadow bird-structure: the earliest mammals, in the pelvic-pouch process of maturing their young, seem only partially to have advanced beyond the oviparous and incubationary process of birds; the flying reptile prefigures the flying Bat; the earliest fossil bird, in its osseous structure,

exhibits the lacertian tail; and birds only gradually and later on lose reptilian traits. Animal life appears to have advanced more rapidly in its latter stages; but occasional indications of linking affinities are still to be detected. And, thus, some subtle sympathy (perhaps having an hereditary source) seems to connect all life in mysterious unity.

At length, *Man* appears upon the scene—and under conditions strange, and such as by which *he* alone could have been distinguished. The existence of every other life-form has been made known only by its fossil fragments—by its bodily self: but the *mind* of Man has yielded the earliest indications of his being; for, in Geological sequence, the first occurrence of his bodily remains is greatly preceded by that of his handiworks. Rude though they be, these exhibit the intellectual qualities of purpose, contrivance, and the adaptation of means to an end, widely separating their possessor from all other living entities; and the germs of intelligence and manipulatory power thus primarily displayed, through long-sustained and ever-increasing mental and physical culture, have developed into the science and civilization of the present time.

Geology—stratigraphical and palæontological—has thus taught us much of the great Physical and Life History of the Earth, brought down to the era of our own Race: but it leaves us here, with no certain initiation into the mysteries of the future—no penetration into the infinite unknown.

THE END.

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